Noise and Hearing
Volume 1
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Noise and Hearing

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VOLUME 1
Readings for the Medical Examiner
Assessing Cases of
Occupational Noise-Induced Hearing Loss

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Scientific Publications Department of the National Center for Scientific,
Technical and Economic Information, Warsaw, 1980.
Preface

This first volume of *Readings in Noise-Induced Hearing Loss* grew out of advice given to expert medical witnesses by a London solicitor (M.A.M.S. Leigh) in Foy and Fagg (1990), a textbook on medicolegal reporting:

There has been a recent development in the practice relating to medical negligence actions which is likely to spread to other personal injury actions, whereby the parties are required to exchange lists of written material, published or unpublished upon which the expert medical witnesses intend to rely in support of their opinions [Naylor v. Preston AHA (1987) 2 All ER 353]. It is hoped that this direction will prevent a party from surprising his opponent at the trial by relying on specific medical or scientific literature in support of his case without affording the opposing party the opportunity of considering the supportive material before trial. It is not intended that a medical expert should conduct a thorough search of medical literature to find any printed material to support his opinion. Rather, it is hoped that there will be disclosure of the printed material on which the expert has particularly relied when making his report. It is good practice, therefore, for an expert to refer in his report to any published opinions or literature which he has used in the preparation of his report or which he thinks will assist the court. (at p. 22)

This volume of readings, together with the associated listing of standards, is much more than a list of references. A note appended to each reference provides the requisite knowledge, including, on occasion, a critique of that reference, that would support arguments, material, and methods in a medical examiner’s report together with responses that might be required at a court hearing.

The notes that follow the references are not intended to be a summary of the corresponding publication. The abstract, summary or conclusions of any of these references may be found on consulting these references. To help the reader the page number of the point to which reference is made here is given where appropriate.

These readings do not represent a complete literature search on the topic, or topics, under discussion, nor were they intended to be so, but
represent the bulk of references that have been found to be of value in the formulation of opinions in cases of alleged or accepted occupational noise-induced hearing loss.

The meanings of the various abbreviations and technical terms are given in the glossary. The glossary stems independently from advice given to expert medical witnesses by the head of litigation services at a firm of solicitors, who advised that such a glossary should be appended to medico-legal reports (Balen, 1998).

These readings provide a basis for a well-grounded, coherent perspective on the assessment of cases of alleged noise damage to hearing. They will provide useful background reading to examiners who have been unable to attend anything other than short courses in the subject. They should be of help not only to medical examiners but also, we would hope, to members of other disciplines involved in actions relating to alleged or confirmed noise damage to hearing.

This publication has been timed to coincide with the new rules for expert witnesses. In the May/June 1999 issue of a ‘bi-monthly review of ENT and audiology’, a Queen’s Counsel drew attention to procedural changes in civil litigation in the UK that had taken place in April (Foy, 1999). These changes followed recommendations by Lord Woolf who was concerned that some experts had failed to retain their independence. The Queen’s Counsel pointed out that a medico-legal report in future should ‘give details of any literature or other material which the expert has relied on in making his report’. Despite the changes, the golden rules for preparing medico-legal reports remain the same, including ‘keep up-to-date with developments and literature in your field’. In commenting, a solicitor (Clement-Evans, 1999) drew our attention to the words of Mr Justice Cresswell in a legal case (National Justice Compania Naviera SA v Prudential Assurance Company Ltd, ‘The Ikarian Reefer’ [1993] 2 Lloyd’s Rep 68, 81–2) which included ‘Facts and assumptions upon which the opinion is based should be stated, with material facts which could detract from the expert’s opinion being considered.’ A barrister writing in the British Medical Journal (Friston, 1999) pointed out ‘that clinicians will now have to set out not only their own professional views, but also those of any other “relevant recognised body of opinion”. This is likely to make the writing of medicolegal reports a lengthier and more demanding process, especially in view of the fact that the courts now expect reports to be well referenced and logical.’
References

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PART I
REFERENCES
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How doctors go about making decisions, including those of diagnosis. Argument that it is a pattern-recognition exercise. Applying this concept to the diagnosis of occupational noise-induced hearing loss it leads us, at least in mild cases or in the initial stages of more severe cases, to a search for high-tone audiometric notches at, or around, 4 kHz (Perlman, 1941; Larsen, 1952; Robinson, 1976). This is sufficiently characteristic to have been referred to as the ‘signature’ of noise damage.

How doctors go about making decisions, including those of diagnosis. Presentation of case histories to demonstrate that it is a pattern-recognition exercise.

ABPI DATA SHEET COMPENDIUM 1994–95. Datapharm Publications Ltd, 12 Whitehall, London SW1A 2DY.
Source of information for doctors on the pharmaceutical preparations that are available, their presentations, uses, doses, methods of administration and contraindications, together with any particular warnings. Data sheets are supplied by individual companies in order to comply with the Medicines Act 1968 and follow the requirements laid down by The Medicines (Data Sheet) Regulations 1972.

Importance of various frequencies. Experimental demonstration that frequencies above 2 kHz are not important to the understanding of speech in a noisy background.

Unpleasant subjective effects (headache, nausea, tinnitus and fatigue) experienced by some individuals exposed to industrial ultrasonic sources attributable to high-level noise in the higher audible frequency range.

Judicial observations regarding the diagnosis of noise-induced hearing loss where degrees of probability have been given. In ‘McGuinness v. Kirkstall Forge Engineering Co. Ltd (1978) (22 February 1979, unreported) Queen’s

1 Also previous and subsequent years.
Bench Division, High Court, Liverpool, the judge considered that 5% was too small a probability when there was a competing and quite satisfactory medical explanation of the hearing loss’ (at p. 206).


The 50 dB 6 kHz notch is due to factor(s) other than noise. A case report.


Provides an explanation for claimants whose hearing threshold levels are insufficiently elevated for them to have perceived specific auditory disabilities. Possible symptoms of occupational noise-induced hearing loss are listed.


Relevance of statistics to the application of the law as statisticians see it; can we now infer the part that statistics should play in the medical examiner’s report?


Generalized linear interactive modelling, the statistical technique used by the Medical Research Council to analyse the data from the National Study of Hearing.


(a) A good account of the way this works in Canada under the Workers Compensation Boards in each of the 10 provinces and two territories. (b) ‘Low fence’: the various provinces of Canada vary in the frequencies taken into account in compensating for ONIHL (Ontario and most other Provinces use the four frequencies 0.5, 1, 2 and 3 kHz; British Columbia and Quebec use the three frequencies 0.5, 1 and 2 kHz) and the average HTL that needs to be reached in order to receive compensation (for Ontario it is 35 dB, for British Columbia, 28 dB, and for Quebec, 25 dB HTL). (c) Appreciation that a threshold for compensation may not correspond to a disability threshold as ‘in Ontario a claim is allowed and the

claimant is eligible for a hearing aid with an average four-frequency hearing loss of 25 dB, although no pension is awarded until the hearing loss reaches 35 dB’ (at p. 893). (d) There is a dearth of Canadian professional experience derived from case law: ‘lack of court cases and adversary confrontation in law’ (at p. 893).


A useful review of the state of knowledge about hearing-protective devices, being the proceedings of an international symposium (more than 50 speakers drawn from six industrialized countries) held in Toronto in 1980.


The value of hearing aids in occupational noise-induced hearing loss:

We went into the question of hearing aids with our compensation patients, of whom we have seen about 10,500. They are often told by their own audiologist that a hearing aid will not help them [in the UK we have experienced the reverse situation, i.e. an ENT specialist has told someone with noise damage to the hearing that a hearing aid will not help, whereas an audiological physician or scientist has said that this is not the case]. Surprise, they do help, and over the past five or six years we have completely changed our view. (p. 343)


(a) Diagnosis of noise damage to hearing ‘ultimately is a diagnosis made by exclusion . . . The situation would be more satisfactory if there were positive rather than negative diagnostic features’ (at p. 626). (b) If there has been hazardous occupational noise exposure, it does not follow that any hearing loss must be attributable to noise damage. ‘The most widespread error and one which is frequently made by those dealing with occupational hearing loss in an epidemiological context, is to suggest because hearing loss is present and there has been adequate noise exposure, that the two are causally related’ (at p. 626). (c) The presence of other disease does not preclude any co-existent noise damage to hearing (at p. 626). (d) Which noise-induced permanent threshold shifts can serial audiometry detect? ‘Most authorities agree that a shift of 15 dB or more with two frequencies should be a trigger for referral’ (at p. 631). (e) Re. relevance of hearing threshold measurements at 6 kHz: none of the 15 audiograms that he uses to illustrate his chapter show hearing threshold levels at 6 kHz. (f) All 15 audiograms show evidence for what could be considered the lower frequency limb of a 4 kHz notch, which limb is associated with a less steep
falling threshold at lower frequencies. (g) Use of formulae in the diagnosis of occupational noise-induced hearing loss: conspicuous by their absence. (h) Ethical considerations: ‘the first responsibility of the examining physician is the welfare of the patient’ (at p. 426): therefore physicians need to be aware of labelling. (i) Potentiating effect of whole body vibration on likelihood of noise damage to hearing: ‘considerable variability and the changes shown were small, perhaps even within the range of experimental error’ (at p. 613). (j) ‘Acoustic accident’ is not mentioned so one might infer that the author does not recognize this as a distinct entity.


Prevalence of tinnitus in Ontario workers. Reported that tinnitus ‘was present in 58% of claimants, and was rated as a major problem in 19%’. Some of the claimants would have been hard rock miners involving exposure to acoustic trauma as well as what we call occupational noise-induced hearing loss. Indeed the author found that tinnitus was more likely to be reported by workers exposed to impulse noise. However, unlike the results of other studies, the likelihood of tinnitus being reported did not relate to the hearing threshold level. Subsequently, the same department reported on the characteristics of the tinnitus ‘in this select group (claimants)’ (see McShane, Hyde and Alberti, 1988).


(a) Audiometric configuration:

Much is made of the shape of the audiogram in noise-induced hearing loss, with the suggestion that a notch centred about 4 kHz with some recovery above this frequency is a prerequisite for the diagnosis. This is not invariably true. First, notched audiograms may occur in the absence of noise, e.g. as a response to ototoxic drug exposure, or sudden hearing loss. Second, the notch of noise-induced hearing loss may range between 3 and 6 kHz and, after a period of time, the high frequency recovery above the notch disappears, leaving a non-descript high frequency loss. The slope may be abrupt, the ski-slope type of loss, with normal hearing to 1000 to 1500 Hz followed by a drop to as much as 30 dB/octave, or it may be shallower. By contrast the loss may show a gentle slope, a relatively common finding after many years in drop forging or high noise exposure. Thus, audiometric shape is only a guide to diagnosis. With so many different types of noise exposure added to ears of different susceptibilities, this should not be surprising. However, flat audiograms, or those which are upsloping are quite unlikely to be caused by noise. (at p. 2/11/22)

3 Haynes et al. (1978).
(b) Tinnitus and industrial noise exposure (at p. 2/11/15):

Tinnitus is a constant feature of an acute blast injury and is a fairly constant concomitant of industrial hearing loss; it is frequently present for some hours after noise exposure, but fortunately usually, but not always disappears. However, after many years of exposure it may become permanent. This is a distressing symptom, which is difficult to quantify and thus difficult to study [this is not the case as the MRC-sponsored tinnitus research at the Institute of Laryngology and Otology, London, over the decade subsequent to 1982 has shown (see Hallam, Jakes, Chambers and Hinchcliffe, 1985; Hinchcliffe and Chambers, 1983)]. The prevalence of chronic tinnitus in workers exposed to noise is high, between 50 and 60%; both the series of Axelsson and McShane (McShane, Hyde and Alberti, 1988; Axelsson and Barrenås, 1992) found it usually to be tonal, sometimes relieved by a hearing aid, and of greater prevalence in those exposed to impact noise. Tinnitus is such a ubiquitous symptom in the population at large that its relationship to noise exposure may only be incidental in some cases. Hinchcliffe and King (1992), in a recent study, suggested that it is frequently a symptom of compensation and pointed out that it used not to be a complaint. [What these authors did say was: ‘Perceptions of tinnitus, and attitudes towards tinnitus, have been influenced considerably in recent years by the mass media and health education programmes, particularly in industry. Noise awareness campaigns in industry may well, in some instances, have converted a complacent management and workforce to a set of over-anxious individuals who say ‘I have worked in noise all my life so how can my hearing be normal?’ Moreover irresponsible programmes by the mass media have had sufficient coverage of workers that the clinical picture of, for example, occupational noise-induced tinnitus has been substantially changed.’] The evidence that tinnitus in noise workers has been influenced by claims derives, at least in part, from publications emanating from this chapter author’s own department (McShane et al. is quoted specifically by Hinchcliffe and King). They also reviewed the history of the subject and its medico-legal implications. Their papers form a contrast with others, such as Axelsson and Barrenås (1992) which are more accepting of tinnitus as a component of noise-induced permanent threshold shift. Both Alberti (1987) and Axelsson give good correlates of tinnitus in noise-induced permanent threshold shift with other aspects of the disorder.

(c) Continuing deterioration of hearing after hazardous occupational noise exposure has ceased:

It is generally accepted that when noise exposure ceases the hearing will not worsen, and indeed may even improve. In the long term hearing worsens as one gets older, and this is as true of the noise-exposed worker as the population at large.

---

4 As a semeion or as a symptom?
5 The authors of this book consider that ‘may be’ would have stated the position more accurately.
6 Tinnitus may still be a symptom, as opposed to a semeion, and not be distressful.
7 Correlation, however, does not necessarily mean causation – see Berkson 1955, Hill and Hill 1991.
However, there is no evidence to suggest that the worsening is caused by prior noise exposure, so long as the exposure has ceased. In all people there is an additional central ageing effect making it more difficult to discriminate speech in a background of noise, which is not necessarily linked to worsening of the pure tone threshold. So there may be general complaints about hearing becoming worse, even with no change in permanent threshold shift. Prior noise exposure plays no part. (at p. 2/11/15)

(d) Marked inter-individual differences (see author’s Fig. 11.15)
(e) No mention of hyperacusis.


(a) A criterion for asymmetry (‘inequality’ strictly speaking) of hearing threshold levels in occupational noise-induced hearing loss (an average difference of 15 dB or more between the two ears for the frequencies of 0.5, 1, 2 and 4 kHz). (b) ‘Unilateral or asymmetric sensorineural hearing loss has relatively serious connotations in otology, for it may be the first sign of a variety of cochlear or possibly more important retrocochlear disorders such as acoustic neuroma, or posterior fossa meningioma. Conventional wisdom thus suggests that a claimant for compensation who has occupational hearing loss and also asymmetric hearing thresholds is unlikely to have noise-induced deafness in the worse ear, and like any other patient, should be investigated for other causes of the sign.


Arguments of a legal school that opposes use of Bayesian statistics (subjective probabilities) in evidence:

Use of Bayesian probability theory in evidential assessments, as exemplified by the likelihood ratio approach, is misleading in two respects. First, the theory mischaracterises the process of juridical proof. Second, the conditions under which it has been useful have not been conveyed successfully to other disciplines, like law, which are ultimately concerned with factual truth. (at p. 271) [This was CGG Aitken’s construction in summarizing Allen’s point of view for readers of the Journal of the Royal Statistical Society]


Experimental demonstration that it is unjustifiable to assume that hearing ‘ability’ is the complement of ‘disability’.

8 Quoted by Aitken (1997).
Suppose we set out to discover the chances of John Brown to make good on parole, and use for the purpose an index of prediction based upon parole violations and parole successes of men with similar histories. We find that 72% of the men with John's antecedents make good, and many of us conclude that John, therefore, has a 72% chance of making good. There is an obvious error here. The fact that 72% of men having the same antecedent record as John will make good is merely an actuarial statement. It tells us nothing about John. If we knew John sufficiently well, we might say not that he had a 72% chance of making good, but that he, as an individual was almost certain to succeed or else to fail. (at p. 16)


(a) ‘Distinguishing features’ of occupational noise-induced hearing loss:

- It is always sensorineural, affecting hair cells in the inner ear.
- It is almost always bilateral. Audiometric patterns are usually similar bilaterally.
- It almost never produces a profound hearing loss. Usually, low-frequency limits are about 40 dB and high-frequency limits about 75 dB.
- Once the exposure to noise is discontinued, there is no significant further progression of hearing loss as a result of the noise exposure.
- Previous noise-induced hearing loss does not make the ear more sensitive to future noise exposure. As the hearing threshold increases, the rate of loss decreases.
- The earliest damage to the inner ears reflects a loss at 3000, 4000 and 6000 Hz. There is always far more loss at 3000, 4000, and 6000 Hz than at 500, 1000 and 2000 Hz. The greatest loss usually occurs at 4000 Hz. The higher and lower frequencies take longer to be affected than the 3000 to 6000 Hz range.
- At stable exposure conditions, losses at 3000, 4000 and 6000 Hz will usually reach a maximal level in about 10 to 15 years.
- Continuous noise exposure over the years is more damaging than interrupted exposure to noise, which permits the ear to have a rest period.

Many of these ‘distinguishing features’ are not specific to occupational noise-induced hearing loss.
(b) Who makes the diagnosis and how is the diagnosis made? ‘The diagnosis of noise-induced hearing loss is made clinically by a physician’.

ANON (1896) Street noises. The Lancet, 4 July, p. 36.

Complaints about traffic noise were just as prominent a hundred years ago, and with the same expectation that something could and would be done about it (by legislation): ‘At last there appear some signs that in the course of the next few years or so some of the totally unnecessary noises of London may be checked . . . There is Mr Jacoby’s Bill all ready; let the Government pass it, or if they do not like that Bill give the County Council powers to make the by-laws it wants.’


A case of ‘industrial sudden deafness’: bilateral permanent hearing loss in range 2 kHz/6 kHz after 30 minutes’ exposure to 160 dB SPL.


Explanations for some developmental anomalies:

the individual in its development seems to repeat hastily and imperfectly its own evolutionary history. This re-enactment is greatly blurred both because of the dropping out of many important steps and by the introduction of extraneous, interpolated features that comprise relatively recent adaptations to uterine existence . . . In accordance with this so-called law of recapitulation (‘ontogeny recapitulates phylogeny’) some theorists have compared . . . the embryo with gill slits to a fish-like stage. (pp. 12–13)


Normality and a ‘low fence’: ‘the limit between normal and abnormal hearing threshold levels is usually drawn at 20 dB HL. Values better than 20 dB thus do not differ significantly from zero and represent normal auditory sensitivity.’


(a) (i) Need to compare like with like:

---

9 Acoustic trauma.
A central problem in a case-control study is the method by which the controls are chosen. Ideally, they should be on average similar to the cases in all respects except in the medical condition under study and in associated aetiological factors. Cases will often be selected from one or more hospitals and will then share the characteristics of the population using those hospitals, such as social and environmental conditions or ethnic features. It will usually be desirable to select the control group from the same area or areas, perhaps even from the same hospitals . . . (at p. 178)

and (ii) need to take into account age and sex differences: ‘the frequencies with which various factors are found will usually vary with age and sex. Comparisons between the case and control groups must, therefore, take account of any differences there may be in the age and sex distributions of the two groups’ (at pp. 178–9).

(b) Properties of the normal (Gaussian) distribution (at pp. 72–7); (c) dangers of extrapolation: ‘The danger of using the wrong model is particularly severe if an attempt is made to extrapolate beyond the range of values observed’ (at p. 165).


Endorsement of the 1980 World Health Organization (WHO) model for impairment, disability and handicap, but no mention of ICIDH-2. The WHO’s *International Classification of Impairments, Activities and Participation – A Manual of Dimensions of Disablement and Functioning*, which has been out for consultation for some time and as of 1999, will replace ICIDH-1 (the WHO 1980 International Classification of Impairments, Disabilities, and Handicaps); ‘disability’ has been replaced by the activities (A) dimension, and ‘handicap’ by the participation (P) dimension.


Improvement of hearing threshold levels of noise-exposed workers after a weekend away from noise, but even this time for recovery is inadequate.


Tinnitus associated with occupational noise-induced hearing loss: 33 out of 55 foundry workers had experienced tinnitus.

---

10 Or factories.
11 Or factories.
12 Or magnitudes.

(a) Prevalence of auditory symptoms associated with hazardous occupational noise exposure: even when he had been employed 30 years in a job with an $L_{eq}$ of 118 dB(A), a man in the 40/49 years age bracket would be more likely to be without symptoms (strictly speaking, *semeions* (not *symptoms*) as the responses were obtained by a questionnaire) of occupational noise-induced hearing loss. (b) Prevalence of *severe* symptoms: 'About a quarter of those with symptoms' (at p. 164). Definition of 'severe symptoms':

Difficulty in conversation, individual and group, at home, work or outside is a common occurrence. There is difficulty in hearing what is said at public meetings. The man finds that people fail to speak clearly and very often speech on TV is indistinct. The sounds of home and street are often missed and difficulty is sometimes experienced in direction and distance of sound. He is aware that his hearing is not normal although he claims his difficulty imposes no restriction on his social or personal life. He knows that other people notice his difficulty in hearing. He quite often becomes irritated with himself because he is unable to follow conversations and there are occasions when he feels cut off. He does get tinnitus but it does not trouble him. (at p. 165)


A conflict between the medical monitoring of workers and human rights: need to consider (a) the integrity of the person; (b) the equality of workers’ opportunity without their being hindered by discrimination; and (c) the right to privacy.


(a) Impact of hazardous occupational noise exposure on the worker: ‘The median clinical picture for these men is of an essentially trivial disorder of hearing’ (summary). (b) Tinnitus is not a prominent feature of occupational noise-induced hearing loss – at least in dropforgers.


\[15\] With a noise immission level of 133 dB (NI).
The possibility of detecting noise damage to hearing with Kemp’s ‘echo’: ‘DPOAEs . . . are not sufficiently sensitive to identify NIHL’ (Abstract).


Daily intake of 167 mg of magnesium associated with a significant decrease in incidence and severity of noise-induced hearing loss.


Comment on ‘Black Book’. Failure to take socio-acusis into account: ‘It is well known that non-occupational noise exposure contributes to most hearing loss, but very little is mentioned about non-occupational noise.’


(a) Review of causation, features and treatment of tinnitus, but it is selective, excluding from consideration a number of publications (other reviews, experimental induction of tinnitus and studies ‘dealing primarily with legal and compensatory issues’). The review refers to 25 selected papers but, as this list of references indicates, another 50 or so are relevant to this topic and provide a different interpretation of the tinnitus/noise relationship from that which is reached by these authors. (b) In support of their thesis, the authors cite the 1984 paper of Meikle and Taylor-Walsh as providing evidence that ‘if we examine populations consisting of patients with tinnitus . . . 80 per cent will show a history of previous damaging noise exposure (Table 23-3)’. This table is headed ‘Prevalence of Previous Occupational Noise Exposure in Tinnitus (T-) Patients’. This is not what the Meikle and Taylor-Walsh paper says. (c) Delayed onset tinnitus: authors report results of their ‘own study of 76 industrial workers who had been referred to the Department of Occupational Audiology for assessment of their hearing loss’: ‘the average delay between the time of first being employed in a noisy environment and the appearance of tinnitus was 23 years’; but no mention of either referral criteria or criteria for the identification of ‘tinnitus’.

14 Specifically, acoustic trauma (gunfire) in recruits.

15 Not strictly true as it uses the paper by, for example, McShane and his colleagues.

Young Swedish men who are being conscripted into the Army have better hearing than an age-matched random sample of British men.


Tinnitus is apparently a greater problem in Swedish workers with hazardous occupational noise exposure. However, depending on the category, 80% to 100% had participated in military service. As most had been born between 1920 and 1930 one would suspect that they had not been provided with hearing protection during gunfire exposure. Unfortunately the Swedish paper does not indicate what proportion of the occupational noise-induced hearing loss these tinnitus cases represented, nor how disturbing was the tinnitus. We are, however, told that the ‘most common subjective discomforts were concentration difficulties, insomnia and decreased speech discrimination’ but no data are given on prevalence, degree of discomfort, or psychological factors. The latter are crucial in view of the relationship between tinnitus and depression.


Potentially hazardous noise levels in the ‘Lynx’ helicopter.


The standing of Bayesian statistics in English law: ‘Introducing Bayes theorem, or any similar method, into a criminal trial plunges the jury into inappropriate and unnecessary realms of complexity, deflecting them from their task.’


The standing of the book:

No reader of this Journal will need to be reminded that the author of this outstanding work is almost unique in being, not only one of the most highly respected teachers and practitioners of clinical otology, but also one of the world’s leading authorities in the pathology of this highly specialised field . . . Professor Schuknecht is generous in

16 In contrast with British workers.
17 Ninety-four patients with noise-induced hearing loss.
his tributes to those who have taught him and those he has taught – and who, in the present generation of practising otologists, has not benefited from his teaching, either directly or through his massive output of written contributions? But essentially, and despite an extensive bibliography, this is a personal book – not so much a ‘Pathology of the Ear’, more a ‘Scientific Basis of Otology’. All who read it will share the author’s own view that this is his opus magnum; and anyone who reads it will become a better otologist for having done so.


There are considerable interindividual differences in loudness perception, so there is a need to determine an individual loudness function for each individual claimant if the loudness of his tinnitus needs to be known.


An approach to assessing the disabilities, limitations in activity, handicaps, and restrictions on participation resulting from impaired hearing.


This paper refers to diseases that become evident only in adulthood, other than congenital or childhood diseases that persist. If such diseases can be determined by factors in pre-adult life so, presumably, can the level of ‘normal’ functioning of the various organs, including the ear. Hence the need to consider normative data for hearing that apply to a country where an adult had lived in earlier life.


(a) Tinnitus occurs early, if at all, in the course of hazardous occupational noise exposure and is not a prominent feature of hazardous occupational noise exposure. Barr’s study has been referred to as ‘The first systematic study of occupational noise-induced hearing loss in Great Britain.’

(b) No mention of hyperacusis.


What should a report include? ‘If the expert’s opinion is to carry proper weight he must show that he has already taken account of all facts which

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might tend to weaken his stated conclusions on the issues with which his report is concerned.’


Different approaches towards reasoning regarding causation. Author argued that scientific and legal reasoning represent different approaches to different questions and provide different solutions. Scientific assertions are biostatistical and probabilistic and express the uncertainty of truth. Legal adjudications are individual, deterministic, and express the fiction of certainty (at p. 272).


Frequencies affected by hazardous occupational noise exposure: occupational noise level ‘does not noticeably affect the hearing threshold (for frequencies) below 3 kHz’.


Socioeconomic factors affecting hearing.


Report of cases of sudden hearing loss during the course of sustained high-level noise exposure. They are designated as ‘acoustic accidents’ but are probably in the group referred to previously as ‘industrial sudden hearing loss’.


Announcement of an audiometer (automatic, self-recording) that solved the problem of operator (audiometrician) variability by putting the selection and presentation of test sounds, as well as the detection and recording of a response, under the control of the machine.


The meaning of the term ‘probability’: Bertrand Russell is purported to have said ‘Probability is the most important concept in modern science, especially as nobody has the slightest notion what it means.’

19 Quoted by Aitken (1997).

(a) Influence of family on legal reasoning: ‘the neighbour dictum in Donoghue (or M’Alister) v. Stevenson [1932] AC 562, was the product of conversations between Lord Atkin and his family’ (at p. 49 of the Bell chapter). (b) Rationality of legal decisions:

The inadequacy of the deductive model of legal reasoning has led some to suggest that decision-making is a matter of ‘hunch’, rather than of deliberation, and that reasons are found thereafter to rationalize the conclusion reached. The importance of psychological factors in the explanation of judicial decisions, even if not taken to the lengths of ‘gastronomic’ jurisprudence – that everything is a result of what the judge had for breakfast – would reinforce doubts about the rationality of legal argument. Add to this picture the doubts cast by some philosophers on the rationality of value-judgments, and we seem to lose hope that there can be a rational debate of what is legally correct. (at p. 60)

(c) Predictability of legal decisions: ‘Even within the range of what is rational, considerable scope is left for divergence of opinion about what is legally correct. The need for value-judgments and the recognition that lawyers will differ in interpreting legal standards give rise to the nightmare of unpredictability’ (at p. 61).

(d) Accountability of legal decisions:

Underlying the two previous criticisms of legal reasoning is the suggestion that the subjective aspect of decision-making gives the reasoner, particularly the judge, power which is uncontrollable. The account of legal reasoning as justification to a legal audience helps to dispel this idea of irresponsibility in that the exercise of power has to be justified by the giving of reasons . . . Meeting the judges’ notions of what is acceptable may not even provide arguments which the rest of the legal community is able to share, let alone the wider community, which constitutes the ultimate body to which political power has to be justified. (at pp. 62–3)

(e) Interaction of these various facets:

The idea of a canon of acceptable arguments elaborated in the practice of the legal community . . . may over-stress the constrained nature of legal reasoning and underplay the degree of its overlap with moral and political reasoning in general. For instance, it may be used to hide the fact that, in easy cases, judges are carrying out particular political policies, and, in hard cases, they are making value-judgments substantially similar to those of other branches of government. (at p. 64)

Likelihood that the acousticians at NPL could select a hyperbolic tangent in using functions to incorporate in one or other formula, for example that used to express the noise immission level concept: ‘A further source of confusion which has originated in the literature is the choice of hyperbolic function for expressing the acoustic impedance in a medium . . . Hence, the hyperbolic cotangent (coth) form of the equation rather than the hyperbolic tangent (tanh) form will be used’ (at pp. 307–8).


(a) Multiple effects: (i) annoyance, (ii) interference with communication, (iii) interference with sleep, (iv) temporary and permanent effects on the hearing mechanism:22 impairment of hearing acuity, distortion of sound, effect on loudness preference,23 tinnitus24 (at pp 46–7); (v) stress effects.

(b) Magnitude of problem:

Almost 25% of the European population is exposed, in one way or another, to transportation noise over 65 dBA (an average energy equivalent to continuous A-weighted sound pressure level over 24 hours). In some countries more than half the population is exposed; in others less than 10%. When one realises that at 65 dBA sound pressure level, sleeping becomes seriously disturbed and most people become annoyed, it is clear that community noise is a genuine environmental health problem. (at p. 1)

22 Although ‘The document does not focus on occupational industrial noise’ (Foreword).
23 The report failed, however, to distinguish between the increased sensitivity of the ear to suprathreshold sounds (hyperacusis) that follows acute sound damage, and the increased loudness tolerance that accompanies working in high noise levels, which is an adaptation phenomenon; the latter is not due to an elevated threshold of hearing (which may or may not be present) as it frequently reverts after such exposure ceases; loudness recruitment is a phenomenon that can be demonstrated by particular tests to be present in both acute and chronic noise damage to the hearing.
24 Again there is a failure to distinguish between the tinnitus that follows acute noise exposure, and which may be severe, and that which follows chronic noise exposure, where it is infrequent and not troublesome.
(c) Perception of noise:

Whether a sound is classified as noise depends in part on the quality of the auditory experience (perception) it produces. The acoustical engineer might prefer to classify kinds of sounds according to physical terminology such as white noise, pink noise, speech . . . The requirements for a general model would be extensive indeed. Not only would variables related to the physical features of the noise be required but also variables pertaining to the listener’s attitudes and present activities. Physically identical sound may become noise to one person and music to another, depending on whether one likes Mozart or rock and roll . . . The noise of the neighbor’s lawnmover [sic] may be annoying if (s)he mowed the lawn two days ago, but a pleasant relief if (s)he just returned from a six weeks vacation to clean up an overgrown front yard. (at pp. 47–8)

(d) current control: ‘In the absence of future ambitious noise abatement policies, the noise environment risks to remain unsatisfactory or even deteriorate’ (at p. 1).


Importance of socio-economic factors in general. The authors question the attainability of the World Health Organization’s goal of ‘health for all by the year 2000’ and conclude: ‘No, and not for many generations without concrete and credible actions to alleviate poverty.’


It is unwarranted to conclude that an observed association between two measures, even in a survey, is a meaningful one; selection may be the source of such an observed association, as was subsequently demonstrated\textsuperscript{25} to be the case for relating high blood pressure to neuroticism.

BERRY BF (1973) Ambient noise limits for audiometry. NPL Acoustics Report Ac 60 (2nd) National Physical Laboratory, Teddington.

Calculations for a set of permissible ambient noise levels based on the laws governing the masking of pure tones by noise.


Different acoustic features are responsible for annoyance at different sound levels: ‘at low levels, the feature of tonality is dominant above

absolute level. However at higher noise levels, the feature of absolute level is more dominant than tonality’ (at p. 804).


Over half a million individuals in the age bracket 11 to 49 years have received at least 104 dB (NI) from discotheque exposure; this noise exposure is equivalent to 91 dB(A) over a period of 20 years.


Guidelines:

Guidelines are broad statements of principle, designed to give practical guidance, which are best laid down at National or International level. They are not meant to tie individual . . . clinicians to a set practice, but rather to recommend a framework . . . should be practical, evidence-based . . . and account for the views . . . of patients . . . So guidelines, standards and protocols are valuable tools which allow us to critically examine what we do . . .


Influence of chronic middle ear infection on bone-conduction thresholds (uninvolved ear in 123 patients with one-sided chronic otitis media used as control). Mean threshold (averaged over 0.5, 1 and 2 kHz) was 5 dB poorer on the infected side. The authors concluded that ‘Chronic ear infection is associated with SNHL’. Authors do not seem to have allowed for the Carhart effect, which could have explained their results.


5-HT (5-hydroxytryptamine – i.e. serotonin) dysfunction in depression. This would link suggestions that loudness intolerance is a manifestation, on the one hand, of depressive psychological states and, on the other hand, of 5-HT dysfunction.


Need for impartiality:

As is widely known, an adversarial system of examining the merits of cases is operated in most parts of the UK. Thus the plaintiff’s case is put and is supported by
evidence; then, the defendant’s case is similarly put and supported. It follows that a clinician may be approached by those acting for either side. In these circumstances of adversarial proceedings the clinician must keep a cool head and maintain an impartial posture. The temptation is great to give the report a bias in favour of the paymaster’s client, in the not unreasonable belief that if this is not done the invitation to report will not be repeated. This temptation should be resisted; the profession of medicine is too august to be sullied by such paltry dealings. Nor should the reporting clinician make a judgement; this is for the judge – as indeed the word suggests. The clinician should display the facts and the evidence as presented, and may then hazard an opinion on the medical aspects of the case. (at p. 4)


(a) Principles of approach to diagnosis by looking at what structural (morphological and histopathological) evidence is available to support individual case assessments:

It is traditional in otology to try to match the clinical picture with the findings from the temporal bone laboratory, wherever possible. As in many other . . . conditions, few patients die of their disease, so the interval between the event . . . and autopsy may be long, and reparative processes may have been at work. Alternatively, the end may come very rapidly from overwhelming disease, which in itself may complicate the histological picture. However, all this is familiar and expected by temporal bone experts. (at p. 420)

(b) There is no mention of hazardous occupational noise exposure being a cause of sudden and/or fluctuant sensorineural hearing loss, nor did any of the publications reporting such cases appear in the nearly 300 references for the chapter.


Concerns difficulties in interpreting an audiogram in terms of the underlying pathology. Experimental studies conducted by the author show that the audiogram does not reflect the complex pattern of cochlear pathology.


Differences in perceptions are a possible basis for inter-examiner variability. There are some figures, such as Necker’s cube, that are perceived differently depending on how one looks at them.

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26 To the best of our knowledge there is no such evidence available in respect of the cases of sudden and/or fluctuant hearing loss attributed to hazardous occupational noise exposure.
Non-acoustical properties of noises, such as controllability, fears, beliefs about maleficent effects, being more important determinants of individual annoyance than the acoustical properties of the noises.


First to advocate A-weighted sound levels – expressing noise levels as dB (A) – as a measure of the degree of hazard posed by sound to hearing.


A single-number approach to assessing degree of protection afforded by hearing-protective devices.


(a) Need for specialists for medicolegal work. (b) Need to include a chronological review in medicolegal reports.


Relationship between several risk factors and the development of age-associated hearing loss in the speech frequencies. Hearing loss defined as an average threshold level of 30 dB HL or greater at the frequencies 0.5, 1, 2 and 3 kHz. Hearing thresholds from 0.5 to 8 kHz using a pulse-tone tracking procedure collected since 1965 on participants of Baltimore Longitudinal Study of Aging. Risk factors considered were age, blood pressure, and alcohol and cigarette consumption. After controlling for age, only systolic blood pressure showed a significant relationship with hearing loss in the speech frequencies. As blood pressure is a modifiable risk factor, results suggest that preventing hypertension might contribute to an effective programme for prevention of apparent age-associated hearing loss.


\(^{27}\) In lieu of the previous method of using octave-band sound-pressure levels.
(a) Typical peak sound pressures for various weapons (at p. 164). (b) Illustrating that exposure without hearing protection to a single round of a Carl Gustav anti-tank gun can be harmful to hearing (at p. 164).


Noise levels of 76 dB(A) to 92 dB(A) in commercial aircraft.


Experts disagreeing regarding risk (relative to *de minimis*):

there may be two equally reputable experts who agree completely about just how small a particular risk is, yet talk . . . as if they strongly disagree . . . One may feel that the situation should be described as reasonably safe, another as not safe . . . each of them, when deciding on the words that seem appropriate, is making all kinds of value judgements.


(a) Figure 1 and Tables I to IV inclusive of the publication refer to the condition of hearing in terms of ‘hearing threshold level’. By 1984 medical examiners in the UK should therefore have been referring to a claimant’s hearing acuity by that term instead of by the term ‘hearing loss’.

(b) The question of *de minimis* and ‘low fence’:

Significant non-compensable components other than due to presbyacusis should be clearly established. Allowing for normal variability of pure-tone threshold determinations and other uncertainties, any such non-compensable component should be at least 20 dB, averaged across 1, 2 and 4 kHz, before it can be regarded as significant. Where any such component is less than 20 dB, it should be disregarded in calculations of the non-compensable disability. In case of conductive components particular care is needed. Where possible the presence of an air–bone gap should be substantiated by clinical signs of major middle ear pathology or by absence, or atypical quality, of acoustic reflexes.

These arguments regarding ‘at least 20 dB’ and being ‘substantiated by . . . signs of major . . . pathology’ could be extended to noise-induced permanent threshold shift. Note 6 says ‘The 20 dB HTL (averaged across 1, 28 See also the paper by Coles, Burns and King (1983), which gives the authors’ arguments for the scheme.
2 and 4 kHz) recommended for the low fence is considered to be a reason-
able and practicable one as the starting point of an impairment/disability
scale.’ As there are no positive diagnostic features (see, for example,
Alberti, 1987a) for occupational noise-induced hearing loss, it is not
possible to obtain the same corroborative evidence for occupational
noise-induced hearing loss (ONIHL) that is required for conductive
hearing losses. If a conductive hearing loss (such as a traumatic perfora-
ton of the eardrum) becomes the subject of a claim, demanding a 20 dB
shift would not be appropriate.

(c) Deciding what is and what is not compensable: ‘It is a matter for the
processes of law to define what is or is not compensable’ (note 9).

Committee Representing the Legal and Medical Professions. London: British Medical
Association.

(a) Role of medical witnesses: ‘Should he regard himself as an advocate for
his side? Or as an impartial witness of the truth? I hope that every medical
man will give his opinion honestly – regardless of whether it favours the
side that calls him – or is against it. Explaining everything. Suppressing
nothing’ (The Rt. Hon. Lord Denning at p. ii.). (b) Attempts by lawyers to
modify medical reports: ‘Should a doctor allow his report to be “vetted” by
the lawyer?’ (p. ii).


Criteria for defining a ‘hearing loss’ of an individual ear: an ear with a
‘mild hearing loss’ (the minimum severity of a hearing loss) needs to show
an audiometric threshold of 20 dB to 40 dB HL averaged over the five
frequencies: 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz; but ‘average
hearing losses of less than 20 dB do not necessarily imply normal hearing.’

BRITISH SOCIETY OF AUDIOLOGY (1992a) Recommended procedure for tympanom-

Definitions for some terms used in aural acoustic impedance measure-
ments, methods for doing these measurements and for reporting results.

BRITISH SOCIETY OF AUDIOLOGY (1992b) Careers in Audiology. 2nd edn. Reading:
British Society of Audiology.

Roles of the various skill groups in the investigation, diagnosis and
management of disorders of hearing: Examples: audiological physician:
‘concerned with disorders of hearing and balance. This includes the inves-
tigation, diagnosis, medical and rehabilitative treatment of patients with
such disorders’ (at p. 4); *audiological scientist*: ‘Member of a multi-
disciplinary team, usually hospital based, which is concerned with identifi-
cation and diagnosis of hearing impairment’ (at p. 6); *otolaryngologist*: 
concerned with ‘The diagnosis and medical, surgical and rehabilitational 
management of disorders, diseases and injuries of the ear’ (at p. 19).


‘Eye witness’ accounts may be wrong, even when supported by other (and 
many) eye witnesses. The chapter headed ‘a display too far’ deals with the 
disintegration before 100 000 pairs of eyes of the prototype supersonic 
DH110 (WG236) fighter piloted by John Derry at the Farnborough Air 
Show on 6 September 1952. Only a few of the 1200 eye witnesses who 
sent in accounts got the sequence of the disintegration correct (comparing 
with a ciné film taking of the accident). ‘Even the experienced 
Farnborough commentator, Oliver Stewart, was eventually proved to have 
got it wrong’ (at p. 77).


Alternative procedures to common law litigation that are available for the 
settlement of disputes.

4–5.

(a) Prevalence of noise damage to hearing in the British Army, institution 
of a hearing conservation programme and little effect of this:

A survey of 100 infantry soldiers, carried out in 1965, showed 54 individuals with 
some degree of perceptive high tone hearing loss consistent with weapon noise 
exposure. Thirty-nine of these cases were bilateral and 30 showed a loss greater than 
30 dB at 3, 4 or 6 kHz. These results, along with other evidence including results of 
research carried out at APRE [the Army Personnel Research Establishment (UK)], led 
to the general issue of hearing protection (the V51R ear plug) to all personnel in 
1966. However, a survey carried out in 1969, and another in 1979, showed little 
change. The 1979 survey also examined the implications for the Army of an audio-
metric screening programme and led on to the present AHCP [Army Hearing 
Conservation Programme].

(b) Attitude of soldiers: ‘Noise-induced hearing loss is rarely seen by the 
soldier as a matter of great importance, especially in comparison to the 
other hazards of the trade.’

29 Army Personnel Research Establishment (UK), Farnborough, Hants.

When taken in conjunction with Gibbin KP and Davis CG (1981) A hearing survey in diabetes mellitus. Clinical Otolaryngology 6: 345–50, this is an illustration of the greater degree of certainty obtainable from an experiment than from a survey. This study, by deliberately manipulating various factors in a well-designed experiment, enables one to determine with considerable confidence the effect of one particular factor (a method of treatment).


(a) Repeatability of manual pure-tone audiometry: very good (0.95 when expressed as a test–retest correlation coefficient, or 5 dB for the lower frequencies and 7 dB for the higher frequencies if expressed as the standard deviation of the difference between the two measurements. (b) Inter-operator variability: no significant change in the repeatability of measured thresholds with different operators. (c) Learning effect: no improvement in threshold on second test; (d) change in threshold required to be considered real: a shift of 15 dB at two adjacent frequencies. All these studies, however, were conducted on well-motivated Royal Air Force personnel by RAF trained audiometer operators.


Importance of the historical perspective:

How is the historical dimension of science relevant to understanding its place in our lives? It is widely agreed that our present attitudes and ideas about religion, art, or morals are orientated the way they are, and thus related to other beliefs, because of their history. And this history needs careful study because the processes by which ideas come and go are complicated. Some would argue that ideas have evolved in competition, by a kind of intellectual natural selection, favoured ones finding social niches; others, for instance, hold that the succession of ideas reflects the succession of groups dominant in society. All this applies to science. Not only are the key doctrines of science . . . central to the modern world, and daily applied in ways ever more closely affecting our lives, but we live within a world in which the outlooks of science – the stress on facts, on experiment, on objectivity – dominate our consciousness and actions.


Examples of noise levels associated with various occupations (at p. 67).

It has been suggested that in many instances otitis media with effusion is the result of acute otitis media that has failed to resolve. The absence of a history of acute otitis media may merely indicate that the preceding infection was subclinical (at p. 64).


The extent to which ear, nose and throat (ENT) surgery practises evidence-based medicine:

Whilst it is pertinent to look at the evidence for practice in a particular specialty, there is a danger that if the results are considered unsatisfactory, others might take this to imply that the specialty was inferior to other specialities . . . Certainly, the medical specialities are more active in carrying out randomized controlled trials than surgeons, one of the main reasons being that they are required to do this before a drug licence is issued. As yet this is not required for surgical procedures . . . What one also wants to known [sic] is how best to arrive at a diagnosis, what the epidemiology of the condition is to understand the natural history and the outcome of the conditions as well as the economics of all aspects.


Vivid case history of effect of acute acoustic trauma (gunfire): Brunner recounted the history of a 36-year-old woman who wrote:

On the 28th February, 1873, I was in a narrow, low room, when outside a musket was discharged near the window on my left side. Instantly I experienced in my left ear a clap which moved whirring and whizzing to the right ear; after that I became dizzy and heard nothing beyond a violent roaring in my head. This agonising condition having lasted a couple of hours . . . everything had a peculiar sound. The following morning . . . when playing the piano I heard the strings vibrating as if they were muffled, but could not distinguish a single tone . . . [Later] I heard the ringing of the church bells for the first time, but they all sounded as if they were cracked . . . From that time (the fourth week after the incident) I could hear as well as to distinguish musical tones . . . My own words echo loud and painfully in my ear on account of which I prefer to remain silent.

Brunner reported that he saw the lady for the first time 37 days after the incident and found

the faculty of hearing and understanding the human voice was still impaired to a considerable degree. When I spoke in the ordinary tone of conversation, she could hear distinctly only at a few feet. With the right ear she could hear my anchor-watch
at a distance of 160 cm; with the left ear at a distance of 80 cm (normal 500 cm). The membrana tympani showed nothing abnormal. The bone conduction was still defective . . . on the sixty fourth day of the disease I made the following notes: Patient feels her head a little clearer and understands speech a little better, the distance at which the anchor watch can be heard is for the right ear 250 cm; for the left, 85 cm . . . The application of Politzer’s bag causes the air to enter both ears pretty normally, but makes no change. The patient hears the tones of the piano clearly when using one ear at a time, and false when using both simultaneously (diploacusis binauralis). The once and twice marked octaves are not so unpleasant to the ear as before. Everything is quiet, but when there is much noise in the room she hears them less . . . Two years later, I saw the patient once more, the distance at which the anchor watch could be heard was 500 cm on the right side; 108–200 cm on the left. She understood speech a great deal better . . . all tuning forks were heard much louder when held before the ears than when placed on any part of the skull.

Thus this picture portrays all the symptoms that can occur after acute acoustic trauma (impaired hearing, tinnitus, distortion, hyperacusis, vertigo), as opposed to the chronic sound trauma of occupational noise-induced hearing loss.


Necessary change in threshold for serial monitoring audiometry to detect an effect of noise (or other factor): 11 dB at 1 kHz, 14 dB at 2 kHz, 20 dB at 4 kHz. Endorses US Department of Labor regulations requiring an average shift over the frequencies 2, 3 and 4 kHz that exceeds 10 dB.


Low-level ambient noise causing an elevation of hearing threshold level (averaging 8 dB in one hour at 1 kHz), a phenomenon distinct from noise-induced permanent threshold shift; probably akin to dark adaptation in vision.


Extent of knowledge of occupational noise damage to hearing by 1970.


Types of audiograms (normal and abnormal) to be found in practice in industry.

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Representative noise levels in British industry.


Extent of population who are disturbed by noise: 56% of individuals are disturbed by noise at home (Table 8.3 on p. 103).


Thresholds obtained by continuous sweep frequency self-recording audiometry about 1 dB more acute than manual audiometry employing a 2 dB-step attenuator and ST & C 4026 earphones.


(a) Much sharper notch in weavers than predicted from NPL Ac 61, possibly because these tables are based on a mathematical model, which, as a consequence of averaging, smoothes the results (not because MRC/NPL survey did not include any weavers, as it examined Kidderminster carpet weavers). (b) Pattern of change in hearing of noise-exposed workers: longitudinal studies of workers exposed to hazardous occupational noise levels (estimated to have been around 100 dB(A) to 102 dB(A)) may show greater changes at 2 kHz than at higher frequencies but this reflects merely the widening of the 4 kHz notch.


(a) Report of Medical Research Council/National Physical Laboratory investigation of noise and hearing in industry (the major source of British data) with a ‘final total of 759 persons’ (at p. 18), relating hearing threshold levels to hazardous occupational noise exposure. The study was commissioned in 1962 by the then Ministry of Pensions and National Insurance and ‘At the conclusion of the investigation, in 1968, we submitted our findings in a report to the Secretary of State for Social Services’. (b) Recognition that there is not just one medical/scientific method for tackling an investigation such as this.

It is generally accepted that there are two different approaches to the kind of problem posed by this study . . . For convenience we will call the two the
‘parametric’ and ‘incidence’ philosophies, and it is the former to which we subscribe. The parametric approach is based on the proposition that the fundamental physiological characteristics of the hearing process are essentially the same for individuals. This basic similarity is overlaid by minor differences due to normal biological variability and within these limits therefore the stimulus-response characteristics are determinate and broadly alike for all persons. In practice, large departures from this state of affairs can, of course, arise due to disturbing factors including pathology of various origins. The experimental approach is therefore to utilise for investigation only ears which are free from such disturbing factors so far as can be determined. The end-product of the immediate investigation can thus be envisaged as a specific relationship between a physical description of noise exposure and the resulting hearing level with, of course, statistical overtones. (pp. 3–4)

(c) Proportion of workers having ear disease: ‘the clinical examination (of the ears) in fact resulted in eliminating about 11%’ (at p. 13). (d) Recognition of non-specificity in diagnosis of noise-induced permanent threshold shift: ‘the absence of any clear-cut diagnostic aid to the identification of permanent noise-induced threshold shift in individual cases’ (p. 4). (e) Pattern of noise-induced temporary threshold shift after a working day: maximum at 4 kHz (Figure 13.1 at p. 187). (f) Pattern of noise-induced permanent threshold shift: shows maximum shift at 4 kHz. (g) Pattern of deterioration of hearing in noise-exposed workers: An interesting rule of thumb can be deduced from the curves which applies with fair approximation to any exposure exceeding 5 years in duration . . . the increment in hearing level is about 0.8 dB per year for high tones, irrespective of noise level. The level attained in the course of the first 5 years, on the other hand, depends very strongly on the noise level’ (at p. 20). (h) Enunciation of noise immission level concept based on equal energy hypothesis to combine level of noise exposure and duration of exposure into a single value. (i) Applicability of survey results to compensation schemes:

31 The ‘incidence’ approach, by considering individuals with a particular diagnosis (occupational noise-induced hearing loss), would be more appealing to clinicians.
32 This choice might also have been determined by one of the principal investigators being a physiologist, and the other a physical scientist.
34 Strictly speaking all the epidemiological studies of this type are sub-experimental studies.
35 Consistent with Keatinge and Laner’s (1958) finding that occupational noise-induced hearing loss develops and is complete within the early years (three) of hazardous occupational noise exposure.
So far we have discussed the hearing impairment solely in terms of the measurable aspect, namely the threshold of hearing. We recognise that any rules formulated to determine compensation must entail a broader assessment of disability. A first step is to translate a pure-tone audiogram into terms of impairment of perception of speech... To enter more deeply into social disability, which would go far beyond what we intended by the present ‘parametric’ approach and would raise questions that could not be answered in any general way. The incidence approach is perhaps more suited to the study of the last-mentioned aspect... (at p. 5)

(j) Applicability of survey results to individual diagnoses:

The application of the results obtained according to this viewpoint would take on the following aspects. First a conventional otological examination with a case history is conducted. Then the audiogram of the individual concerned is compared with basic diagrams, or possibly mathematical equations, describing the relations of noise exposure to hearing level, the diagrams giving also the statistical distribution data. An *a priori* probability is thus established that the

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36 Having regard to what their Lordships said during the Court of Appeal hearing in *Robinson v. British Rail Engineering* [1982] Court of Appeal (Civil Division) No. 489, 3 November, this is precisely what the common law wishes to know about. ‘... the learned judge was faced with the simple task – simple in one sense but not by any means simple in another – of quantifying or putting into pounds and pence, the loss of amenity which the plaintiff has suffered as a result of noise-induced loss of hearing... insurers and trade unions... are interested in any guidance which the courts can give on the conventional figure which should be awarded for this kind of impairment of hearing, or this kind of interference with the quality of men’s and women’s lives... [Council for Plaintiff] says that it is wrong for a judge to look simply at decibels and that the judge has to look at the effect on the particular plaintiff of that particular affliction, with the degree in decibels which it has reached' *per* Stephenson LJ; ‘... a mere comparison of decibel loss is very misleading’ *per* Kerr LJ.

37 The parametric approach.

38 For example, Robinson and Shipton, 1977; Lutman and Spencer, 1991; Lutman, Davis and Spencer, 1993.

39 This does not quite describe the clinician’s approach to diagnosis. The clinician would in fact be comparing the individual’s audiogram(s) to the audiograms of other individuals who had been exposed to hazardous noise levels (for example, Bryan and Tempest, 1979; Johnston, 1953; Schuknecht, 1974) or not (for example, Cawthorne and Hinchcliffe, 1957; Morrison, 1975; Oluwole and Irwin, 1996; Hallpike and Cairns, 1938; Hallpike and Wright, 1939; Schuknecht 1974; Suga and Lindsay, 1976; Suga et al., 1976); the clinician would also be aware of reports of interactions between noise and other etiological factors (for example, Chadwick, 1971b).

40 This is reminiscent of the *prior and posterior* probabilities of Bayes’ theorem, which has been rejected by the Court of Appeal; medical diagnosis is a matter of pattern recognition (see Abernathy and Hamm, 1994; Dunea, 1997; Lee, Ham and Park, 1996)
person has or has not sustained an occupational hearing loss. If there are no other indications and the probability is high, the noise-induced origin of the lesion can be assumed.\(^{41}\) (at p. 4)

(k) There is no mention that tinnitus was a problem in workers with hazardous occupational noise exposure. (l) There was no mention of the existence of an acute form of occupational noise-induced hearing loss. (m) The study was not designed to detect subjects with earpits or other congenital anomalies unless they were associated with a conductive, congenital, or familial hearing loss (see ‘scheme of the otological examination’).


Definition of a database (in the glossary).


Endolymphatic hydrops\(^{42}\) being the most common cause of fluctuating sensorineural hearing loss.


Tinnitus being more of a problem in Israeli cases of acoustic trauma (as opposed to occupational noise-induced hearing loss). This needs to be read in conjunction with Man and Naggan (1981). These Israeli papers concerned younger adults and one paper gave the information that all were males and in 76% of cases the frequency with the greatest loss was 6 kHz. The cases would have been collected in the decade after the 1973 war. Moreover, all these young men would have undergone a period of compulsory military training. We would therefore think that the cause may primarily be attributable to gunfire. Indeed their cases were referred to as being due to ‘acoustic trauma’.


High prevalence of progressive genetic hearing loss in adults: ‘The most commonly misdiagnosed high tone hearing loss is progressive genetic hearing loss in adults.’

\(^{41}\) The correct sequence of medical diagnosis followed by introducing noise/HTL equations was perceived by Tempest and Bryan (1981).

\(^{42}\) A distension of the innermost fluid compartment (membranous labyrinth) of the inner ear; so called because it contains a fluid termed *endolymph*. 

Protective effect of prior exposure to subhazardous noise levels – a ‘toughening’ of the ears – occurs with increasing duration of hazardous occupational noise exposure. For example, a 1 kHz tone at 81 dB SPL for 24 hours completely protects guinea pigs from any permanent effects arising from a subsequent 2.7 kHz tone at 103 dB SPL for 5 minutes.


Depressions in bone-conduction hearing threshold levels that were associated with conductive hearing loss but were improved by surgery and could not therefore be attributed to impaired cochlear or neural function. The bone conduction audiometric pattern characteristically showed notching at 2 kHz – the so-called Carhart notch – now attributed to middle-ear pathology affecting the mechanics of hearing by bone conduction.


Effects of noise on behaviour: high noise levels – 100 dB SPL – interfere with efficiency of certain tasks, for example watch-keeping jobs and inspection tasks.


The melanin factor in occupational noise-induced hearing loss: ‘Average hearing levels of otologically normal left ears were poorer at 4 kHz ($p < 0.05$) for apprentices (industrial apprentices attending trade courses) with eye colours indicating no melanin pigmentation of the iris than for apprentices with melanin iris pigmentation’ (Abstract).


Appreciation by clinicians of the importance of individual noise susceptibility: ‘Another important and still not very well understood factor is individual susceptibility. There can be no doubt that some ears are more easily affected by noise than others’ (at p. 6) . . . (in Discussion):

DR T.O. GARLAND (Central Middlesex Hospital) asked whether the author could say anything about expert evidence in a compensation case. He did not want him to discuss the criteria for the assessment of damages but he would like to know whether the author, as a specialist in his subject, could go into the witness box and
give clear evidence one way or the other that a person’s deafness was due to his work . . . MR CAWTHORNE said that . . . The matter was complicated, however, by the question of individual susceptibility . . . Going into court to give evidence would remain very tricky. (at p. 9)

Partly because of explaining this factor of noise susceptibility, apprehension was being expressed regarding giving evidence in common law actions that were yet to come.


(a) Identity of some plaintiffs’ audiograms with that of a man whom clinicians had diagnosed as having a genetic sensorineural hearing loss. (b) Right–left asymmetry may occur with such hearing losses in the same family.


(a) ‘Low fence’: individuals who attend ENT clinics complaining of hearing difficulties and who are diagnosed as having occupational noise-induced hearing loss all have hearing thresholds at 2 kHz of at least 30 dB.


(a) Extent of pre-employment examination in hearing conservation programmes: ‘I consider a full ear, nose and throat examination essential before any audiogram is taken . . . It would, of course, be ideal to have a complete report of all the various systems, nervous, cardio-vascular, etc.’ (at p. 127). (b) Employability of persons with impairment hearing: ‘I do not therefore consider that a deaf person with diseased ears should by any means be debarred from working in noise’ (at p. 127). (c) Behaviour of already-diseased ears under conditions of hazardous occupational noise exposure. Chadwick said:

Allowing for variations in individual susceptibility, the response of the normal ear when exposed to noise is now well known and largely predictable . . . the manner in which the already diseased ear reacts to noise is less well understood . . . Otology is rarely pure, and dual pathology not uncommon . . . Ménières syndrome. Patients suffering from this condition frequently exhibit intolerance to noise . . . Other types of sensorineural deafness are so numerous and of such varied aetiology that I do not propose here to consider them all individually. Again the general consensus of opinion seems to favour the view of Aram Glorig (1958) who does not feel that when an inner ear lesion is already present the ear is any more susceptible than the normal ear. Perhaps those patients who seek clinical advice are those who prove exceptions to the general rule. As an example I would instance a girl of 19 whom I saw recently. There was a history of deafness on both sides of the family. The patient herself had been unaware of any
hearing defect until she left school at the age of 15 and commenced employment as a machinist in a factory where there were 60 noisy machines in each room. She then noticed a rapid deterioration in her hearing. Her audiogram showed a severe bilateral high tone perceptive hearing loss with marked involvement of the speech frequencies.


The type of mathematical analysis that needs to be done to enable medical examiners to detect audiometric evidence of noise damage to the hearing (high-tone notches). The essence of the approach is to discard the notion of dividing any one audiogram into a number of principal segments where a classification procedure is carried out separately on each segment, and instead to consider any audiogram as a singleton within in its own stochastic nature. The problem is to determine an optimal mathematical strategy for discriminating between the different classes of audiograms in order to attach a statistical significance to each audiogram as being either a member of any one single class, the \( n \)th stage of a progressive condition, or the \( n \)th degree of severity of a condition existing in varying degrees of severity. The mathematical strategies used orthogonal transformation based on the Karhunen–Loève expansion. The optimal orthogonal expansion basis functions were Chebyshev polynomials. The audiograms were smoothed using cubic spline interpolation. The analysis used orthogonal Householder transformation, Gauss–Markov theory, and Sturm–Liouville differential equation properties.


Long time (maybe months) over which hearing may still be recovering after finishing hazardous occupational noise exposure.


(a) Drawing attention to hazards to hearing of sports shooting in developing countries. (b) In this report, use of pistols, where right ear was more exposed to the gun noise.


Occupational noise problems in developing countries.


Nature of complications of otitis media:
Complication occurs when the infection spreads beyond the mucoperiosteal lining of the middle ear. Several general factors influence the development of complications: (1) the virulence of the organism, and its susceptibility to therapy, (2) the host’s immune state and general resistance, and (3) the adequacy of treatment of the primary infection. (at p. 177)


Possibility of severe hyperacusis co-existing with severe hypoacusis (‘a severely deafened ear’) and being sufficiently bad as to require surgical destruction (successful) of the affected ear (in a musician).


Subjective perception of occupational noise-induced hearing loss by workers: ‘Only in comparatively few cases do the workers appear conscious of any inconvenience sufficient to justify the wearing of ear protection.’


Workers in industry (including those exposed to hazardous noise levels) do not constitute a representative, let alone random, sample of the adult population; in some ways they may be more healthy because of self- and employer-selecting processes. This could explain, for example, (a) MRC/NPL data showing that there are more severely hearing impaired people in the general population than in noisy industries, and (b) hazardous occupational noise exposure being a negative risk factor for experiencing, and being troubled by, tinnitus.


(a) Succinct description of occupational noise damage to hearing: ‘1. The damage to hearing caused by noise is insidious and the effects are not obvious except by scientific measurement . . . 3. Noise leaves a characteristic V-shaped signature on an audiogram which is not easily forged by other conditions’ (at p. vi). (b) Compensation, in common law actions, for loss of earning capacity and future loss of earnings43 (at pp. 48–9): a number of cases cited – for example, McCafferty v Metropolitan Police

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43 Referred to as the Smith factor by lawyers (after rules established in Smith v Manchester Corporation [1974])
District Receiver [1977] 2 All ER 756, where an award of £9150 to a ballistics expert for loss of salary due to premature retirement was upheld on appeal (but this was a case of acoustic trauma, rather than occupational noise-induced hearing loss). In Heslop v Metalock (Britain) [1981] in Kemp and Kemp, The Quantum of Damages, London: Sweet & Maxwell, Mr Justice Mustill thought it right to make some award for the chances of employment that would be closed to the claimant because of the hearing loss but he could not put a figure greater than £750 on it. A very unhappy state of affairs prevails in the North East. People can fall out of work without any fault of their own. Where even the fittest man will have difficulty finding employment, the relative disadvantage of the potentially disabled man is less. In Kellett v British Rail Engineering Ltd (3 May 1984, unreported) Queen’s Bench Division, High Court, Chester, Mr Justice Popplewell rejected completely the claim under Smith v Manchester Corporation (1974) 17 KIR 1. It would be difficult, if not impossible, for the claimant to obtain another job even if he were 100% fit. There were many volunteers for redundancy and British Rail could not guarantee his job until 65. The claimant would not have lost his job on account of his deafness.


High prevalence of carriers of the gene for defective hearing: one in eight of the population.


A case of a 56-year-old man who had developed a relatively acute hearing loss some 12 years previously when using a pneumatic hammer; ‘He also had a history of syphilis.’ The sudden hearing loss may therefore have been consequent on the syphilis rather than the noise.


Tinnitus in workers in noisy occupations. (a) Likelihood of a worker answering in the affirmative to the question ‘Do you now have ringing in your ears?’ increases with the level of the threshold of hearing but for no hearing threshold level does it reach a probability of ‘more likely than not’. (b) Overall prevalence (6.6%) of admitted tinnitus in these noise workers is less than that for the general population of the UK44 or the USA45 (the

44 Coles, Davis and Haggard (1981).
data were collected from 30,000 workers in British Columbia who had been exposed to essentially an $L_{ERI}$ of 85 dB(A) or more.


Threshold asymmetry. After excluding effects of gunfire and ear disease, the hearing of the left ear of noise-exposed workers was about 1 dB poorer than that of the right but the difference depended on the test frequency, the hearing threshold level, gender and age, with the maximum difference to be found in 50–54-year-old men for a frequency of 3 kHz and a loss of 30–39 dB HTL, where the difference is nearly 7 dB.


Threshold asymmetry: even when occupational noise exposure is predominantly from one side, the asymmetry in the noise-induced hearing loss is relatively small.


A ‘normal’ selective 2 kHz asymmetry in occupational noise-induced hearing loss: 4.7% of NIHL claimants in British Columbia had a selective inequality of 20 dB or more at 2 kHz, with, in most cases, the threshold inequalities at adjacent octaves being 5 dB or less; in 83% of cases the left ear was the poorer ear; in 50% of cases the inequality ‘could not be accounted for even after the examination of their medical, occupational and non-occupational histories’, so that one would need to attribute it to a lateral difference in noise susceptibility.


Drawing attention to non-occupational noise sources as a potential hazard to hearing.


Complexity of apoptosis.

\(^{45}\) Singer, Tomerlin, Smith and Schrier (1982).

\(^{46}\) Defined as the lateral difference in hearing threshold that is not due to shooting or ear pathology.
A 56-year-old South Wales ‘driver of heavy plant vehicles’ was awarded £165 000\(^\text{48}\) for noise-induced hearing loss on 21 July 1998 at the Cardiff County Court. He had been exposed to a noise immission level of 111 dB (NI) and had a ‘modified average binaural loss’ over 1, 2 and 3 kHz of 29.33 dB; the man was suffering from hyperacusis and severe tinnitus. He was ‘somewhat over-sensitive to sounds such as banging doors, loud music, loud traffic and clattering noises in the house’. The onset of the tinnitus was not until about 30 years after the onset of hazardous occupational noise exposure. Two consultant psychiatrists agreed that the man suffered significant depression secondary to the tinnitus.

\(^{47}\) A claimants’ solicitor specializing in NIHL cases.

\(^{48}\) The main element was for loss of earnings since 1992 and for future losses until retirement.
involved each case will be looked at individually which may lead to different approaches by different courts’. (c) A guarded prognosis: ‘How the new rules will work in practice remains to be seen’ (the author teaches on the Nottingham Course ‘Medicolegal Aspects of Noise-induced Hearing Loss’ for medical, legal and associated professionals).


The need to obtain a high yield, i.e. a low lapse rate, of the target population sample to avoid erroneous conclusions.


The place of mathematics and statistics in medicine.

Although Bernard fully appreciated the importance of mathematics and said that ‘the application of mathematics to natural phenomena is the aim of all science’, he believed that many of the attempts to apply mathematics to physiological problems were faulty because the empirical data were insufficient . . . This rejection of statistics and the implied indeterminism of their application by medical men is closely linked with Bernard’s endeavour to transform physiology into an exact science.


(a) Prevalence of genetic hearing loss:

It has been suggested that there are about 2 million deaf individuals and 12 million hearing-impaired individuals in the United States. The many epidemiologic studies carried out both in Europe and the United States indicate that at least one-third of all cases are hereditary . . . Estimates that one third are hereditary must be a minimal figure because a considerable proportion of isolated causes of unknown cause may, in reality, be hereditary. (at p. 9)

(b) Prevalence of hearing loss as a component of a syndrome: ‘Among known hereditary examples, at least 15%–30% are syndromal, i.e. associated with other anomalies’ (at p. 9).


Value of case reports in expanding the database of clinical medicine: a petty officer with an infection of the urinary tract who developed an
adverse reaction (ataxia and vertigo) after a second course of streptomycin in a relatively low dosage.


(a) Importance of the single case report and its contribution to expanding medical knowledge (the case of Corporal WNN). (b) Existence and extent of intra-observer variation in hearing assessment cases – when viewed in conjunction with Coles and Knight (1965). (c) Hypersusceptibility to noise damage (gunfire) may be attributed to impaired, i.e. elevated, acoustic middle ear muscle reflexes.


(a) Importance of the single case report and its contribution to expanding medical knowledge. (b) Measurement artefacts that can produce a 6 kHz notch, and with as much as 60 dB of notching.


A case of sudden unilateral total loss of hearing during use of a cartridge-assisted hammer, which produced a peak sound pressure of 161 dB SPL; but prior to incident the man ‘already had a considerable degree of perceptive deafness of rather uncertain aetiology’; in common with Japanese cases of sudden hearing loss in noise-exposed workers (Kawata and Suga, 1967), the man had used a percussive tool.


Frequency of exaggeration in claims cases.

Non-organic hearing loss is likely to be a major problem here.49 American evidence, which is supported by our own experience in investigation of medico-legal and head injury cases, suggests that some 25–40 per cent of persons claiming compensation may have a sizeable non-organic element in their apparent hearing loss. (at p. 195)


(a) Non-specificity of symptoms and signs: ‘Diagnosis of noise deafness is difficult. There is nothing positive about it; it is done by exclusion of other

49 The author is referring to the imminent designation of ONIHL as a prescribed occupational disease in the UK.
factors’ (at p. 17). (b) Appreciation that cardiovascular disorders cannot be attributed to hazardous occupational noise exposure (at p. 18).


(a) Status of clinical tests of hearing:

Apart from the whisper test, and perhaps a watch tick test, the tuning fork tests are the otolaryngologist’s mainstay for his clinical assessment of the patient’s hearing ability. They can be used to provide a measurement of ability to hear, but their principal use is in defining the site of disorder. A large number of tuning fork tests have been described, but the two most universally used are the Weber and Rinne tests . . . (at p. 25)

(b) Individual positive as well as negative aspects of hearing loss mean that there is a need to personalize assessments of impairment, disability, handicap and quality of life resulting from hazardous noise exposure:

The writer recalls an occasion when he examined a customs officer who was complaining of difficulty in hearing. This was due, in fact, to a high-tone hearing loss caused by past exposure to gunfire noise. He said that the hearing loss was quite helpful to him in his work; if a wristwatch purchased abroad was of good quality and emitted quiet ‘ticks’, then he could not hear it and he charged duty; if it emitted loud ‘tocks’, then it was cheap and he could let the traveller off. (pp. 24–5)


Just because a person has noise-induced hearing loss this does not necessarily mean that the tinnitus is also noise induced.


A review of the subject of tinnitus with approximately 200 references that were up to date50 and which was written by the Honorary Consultant in Audiological Medicine to the Medical Research Council’s Institute of Hearing Research for the 5th edition of Scott-Brown’s Otolaryngology textbook, which has been referred to as the ‘Bible’ for otolaryngologists; but there were important omissions from the references that are relevant to occupational noise-induced hearing loss.

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50 References up to 1987.

(a) Cause of tinnitus: the clinical dictum that ‘whatever caused the hearing loss, probably caused the tinnitus too’ (at p. 2/18/12) (contrast Coles 1982). This dictum is not widely recognized, although certainly 40 years ago one might well have said that. Since then there has been considerable research on tinnitus, with the need to distinguish whether tinnitus can be demonstrated in any individual, whether an individual would admit to perceiving tinnitus if questioned, and whether or not it is troublesome. There is a need to consider each individual case. Moreover, if this dictum were true, because hearing threshold levels are determined by many factors, there is a need for apportionment. (b) Tinnitus and hazardous occupational noise exposure:

Temporary noise-induced tinnitus and/or dullness of hearing should be taken as a warning that the causative noise exposure could be potentially hazardous to the hearing of the individual if repeated frequently and especially if tinnitus and/or dullness lasts for more than about 5 minutes. (at p. 2/18/3)

No evidence is provided to support this statement.

(c) Hyperacusis: ‘can be defined by the onset of symptoms of loudness discomfort from everyday sounds that previously had not bothered the patient and/or uncomfortable loudness levels for pure tones in the 500–4000 Hz of less than 70 dB HL. As such it has been recorded in 43% of new patients, occasionally with the hyperacusis being more troublesome than the tinnitus.’ (at p. 2/18/11), but it is not stated how many patients actually complained of an intolerance to loud sounds. Moreover the inclusion of patients with lowered measured uncomfortable loudness levels51 would certainly boost the proportion of deemed hyperacusics (lowered thresholds of uncomfortable loudness could well be universal in tinnitus patients).


... a description of the clinical practice and experience of the Tinnitus Clinic at the General Hospital, Nottingham... helpful to ask the patient to describe his tinnitus as best he can... Pure tones should be used for pitch matching... Loudness matches for pure tones are usually done with an audiometer at the so-called pitch match frequency... clinical indications are sufficient to warrant their (matching tests) use while further research is proceeding.

51 Threshold of uncomfortable loudness.
(a) ‘Low fence’:

The low fence is the HTL corresponding to transition between no disability (0%) and detectable disability . . . To define the low fence, three studies of persons with noise-induced hearing loss seem to be most relevant [Acton, 1970; Suter AH (1978) The ability of mildly hearing-impaired individuals to discriminate speech in noise. Report EPA-550/9-78-100. Washington DC: US Environmental Protection Agency; Smoorenburg GF, de Laat JA, Plomp R (1982) The effect of noise-induced hearing loss on the intelligibility of speech in noise. Scandinavian Audiology, supplement 16:123–37]. Their comparison of results of measurements by pure-tone audiometry and by speech audiometry in a background of noise, and also by disability questionnaire in Acton’s (1970) study, suggest low fence values for 1, 2 and 3 kHz average in the range 15–19 dB HTL, as did Kryter (1973) in his scientific analysis of earlier data. Scaled for the 1, 2 and 4 kHz average, these results indicate a low fence of some 20 dB. (at p. 1033)

(b) Disability arising from conductive hearing loss: ‘Conductive hearing loss is ranked as equally disabling as sensorineural’ (at p. 1034). (c) Tinnitus: ‘usually causes little lasting annoyance, sleep disturbance or other stress’ (at p. 1034).

(a) Assessed prevalence of tinnitus in a population depends on how the ascertaining question is framed: for example, for Glasgow, 39% of the general population said that they had tinnitus. If ‘spontaneous tinnitus of short duration’ and ‘temporary noise-induced tinnitus’ are excluded, the prevalence is more than halved (down to 18.6%); it is more than halved again (down to 6.9%) if only annoying tinnitus is considered (at pp. 19 and 21). It is down to 0.5% if only tinnitus having a ‘severe effect on life’ is considered. (b) Significance of ‘degrees’ of tinnitus: the authors say (when referring to previous MRC figures53 for prevalence of tinnitus in the general population) ’These figures are obviously too high to refer to the forms of tinnitus that have real or potential clinical significance’ (at p. 19). It is difficult to understand this statement in view of fact that (i) it can be demonstrated that we all have tinnitus and this tinnitus is indistinguish-

52 ‘This paper . . . outlines the philosophical, medical and scientific rationales underlying many of the details of the method of assessment [i.e. the Blue Book] recommended.’
53 Hinchcliffe (1961a).
able from that of the patients who seek medical advice, and (ii) patients who develop distressing tinnitus may or may not have experienced tinnitus previously. (c) The vast majority of people who have tinnitus do not complain about it.


Acoustics of firearms and their measurement:

This paper presents impulse-noise damage–risk criteria based on conclusions of independent British and American studies and on the work of other research workers in this field. Most of the studies that led to the criterion were performed with noise from small arms, but the criterion is general enough to permit assessment of most other types of impulse noise... The measurement technique and type of transducers to be used are discussed.

(Abstract) acoustical values for the 7.62 mm rifle given as 161 dB peak level at firer’s ear, A duration as 330 µs, and B duration as 5 ms (at p. 342); authors point out the need to measure the complete impulse (waveform, rise-and-decay times, peak pressure) and give correction factors to be applied where necessary to allow, for example, for reverberation, orientation of the head to the noise source and number of shots fired.


(a) Need to enquire about leisure activities:

Unless specific enquiry is directed during a hearing conservation programme towards such spare-time activities, it is more than a theoretical possibility for a high-frequency notch to be attributed to noisy working conditions whereas, in fact, it could be due to participation in shooting as a pastime. (at p. 101)

(b) Authors provide a sample of noise-induced permanent threshold shifts from industrial noise exposure from which it is possible to gain some idea of the hearing threshold levels required to give rise to symptoms (at

54 Heller and Bergman (1953).
55 Comprehensive review: data in this paper were used in the National Study of Hearing to assess each subject’s noise exposure from gunfire.
56 The Belgian FN.
57 A Royal Navy/Medical Research Council study.
pp. 99–101). (c) Mid-frequency notches due to gunfire: case of 19-year-old man who 'had fired about 500 rounds of 0.22 in. rifle as member of a rifle club . . . Never noticed any temporary deafness or tinnitus. Fired from right shoulder' (at p. 102) but HTLs at 1.5 and 2 kHz were only 5 dB greater in left ear; one cannot be sure whether or not this notch was genetic or a latent genetic notch that was brought out by the gunfire.


(a) Importance of the single case report and its contribution to expanding medical knowledge (the case of Corporal WNN), as well as the importance of presenting it for a second time. (b) Existence and extent of intra-observer variation in hearing assessment cases – when viewed in conjunction with 1963 publication.


The new standard will typically yield BC thresholds that are about 3–4 dB less acute averaged over 1, 2 and 3 kHz as compared with the old standard, and about 5–8 dB less acute at 1 kHz in particular, depending on the date of manufacture of the mechanical coupler used for calibration. (at p. 519)

(b) The question of de minimis:

Taking account of all the possible sources of error, only an air–bone gap averaged over 1, 2 and 3 kHz greater than 15 dB can be regarded as significant, when measured with an audiometer whose output is calibrated to BS 6950: 1988. When an audiometer has been used that is calibrated to the earlier standard (BS 2497, Part 4: 1972) only an air–bone gap greater than 20 dB should be regarded as significant.


(a) CERA threshold (1) determining: ‘The whole technique was under computer control giving an estimate of the probability of the presence of a response, and from that automatically selecting the next stimulus level (in not less than 10 dB steps). Final assessment of the response was done
primarily by eye, but was aided by the computer scoring . . . ’ (at p. 72); so it is incorrect to say that ‘the interpretation of the threshold is purely subjective’; (2) guidelines for interpreting CERA, for example ‘Where three or more frequencies in one ear have been CERA tested, if the average subjective/objective discrepancy is over 7.5 dB, some degree of non-organic hearing loss is probably present’; (3) reporting: there is no mention that the ‘way the Cortical Evoked Audiometry results should be reported is with a threshold and a confidence limit of +/- 10 dB placed on it . . . ’ (b) Audiometric patterns: (1) flat audiograms: ‘In the authors’ experience, the vast majority of alleged cases of noise-induced hearing loss with flattish audiograms have a major element of nonorganic hearing loss as well. Of the few that prove to be organic, there is obviously a major possibility of some other diagnosis . . . ’ (p. 76); ‘a flat audiogram is good _prima facie_ evidence for a non-organic overlay in noise-induced hearing loss’ (at p. 77); (2) noise-induced hearing loss: ‘true’ thresholds are distinctly steeper than those predicted by Burns and Robinson (1970). The same is true of the data from the large and careful study of jute workers in Dundee by Taylor et al. (1965) and in a follow-up study by Kell (1975) in the same industry. Likewise, in an analysis of eight different studies of noise-induced hearing loss in industry, including that of Taylor et al. (1965), Passchier-Vermeer (1974) showed more normal hearing at low frequencies and a more prominent audiometric dip at 4 kHz than predicted by Burns and Robinson (1970), particularly in the earlier stages of development of noise-induced hearing loss . . . possible explanations for the flattening predicted from the Burns and Robinson formulae: (i) ‘complication by other forms of sensorineural hearing loss which are quite prevalent in the general population (Davis, 1983)’; (ii) the Burns and Robinson data may themselves have included some cases with non-organic overlay (this is difficult to detect by pure tone audiometry on its own, and is liable to occur in any industrial population); (iii) it may be an artefact produced by their subject exclusion criteria and/or insufficient numbers with high noise immissions (a failing discussed by Kell, 1975); (iv) the audiometers used (Rudmose ARJ-4) had a maximum output of 85 dB, such that they could not have measured hearing losses substantially greater than those shown . . . This would probably have entailed a ceiling effect in measuring hearing levels at the higher frequencies where the hearing losses would usually be maximal. (at pp. 76–7).


(a) Prevalence of nonorganic hearing loss: ‘in the United States, the CHABA organization (1963) have studied the subject and they suggest that 25–40% of claims for deafness have a significant amount of NOHL in them’ (at p. 194). (b) Nature of nonorganic hearing loss: ‘It is sometimes said that nonorganic hearing loss is always superimposed as an overlay on an
organic hearing loss. In our own series of 70 cases this was clearly not so. Indeed, in only 28 out of the 70 cases was there an underlying organic element’ (at p. 196). (c) Value of speech audiometry (i) in detecting NOHL: ‘The speech audiogram is about the best detector test of all. In 53 NOHL cases tested only 27 gave a normal form of response, only 12 gave a good correlation between the pure-tone and speech thresholds (in all but one of the cases of poor correlation the speech threshold being lower, i.e. closer to the real thresholds), and only 5 gave both normal response and good correlation . . . The responses were said to be atypical if they exhibited such characteristics as a change from close to 100% intelligibility score at one level to close on 0% at a level only 5 dB weaker . . . ’ (at p. 197); (ii) in quantifying the hearing loss for compensation purposes: ‘it would certainly be worth while to perform speech tests as well as pure-tone ones and to have a rating scale for disability based on either type of audiometry; presumably, then, the results which indicated the lesser handicap would be the ones used for calculating the amount of compensation for that individual’ (at p. 199). (d) Value of cortical electric response audiometry (CERA) in cases where there is any indication of a nonorganic hearing loss: ‘It would certainly seem to be the method of choice when eventually some reliable and comfortable method is needed for obtaining objective measurements of pure-tone threshold’ (at p. 199).


(a) Experimental demonstration of effects of rifle fire on inadequately protected hearing. (b) Noise susceptibility: ‘Audiograms illustrating . . . the wide range of individual variation in noise sensitivity’ (see legend for Figure 3 on p. 186). (c) This paper illustrates that a single case report (the case of Corporal WNN) may be important in contributing to the expansion of medical knowledge; moreover, the importance is emphasized by it being presented for the third time (or does this indicate rarity?).


Hazards of sports guns to hearing: (a) ‘The writers thank Drs Taylor and Williams for their paper which will add strong support to their own efforts in Great Britain to bring about a greater awareness of the auditory hazards of sports guns and of means of their prevention’ (at p. 1730). (b) Peak level (at firer’s forward ear) of 155 dB SPL produced by 12-gauge shotgun in open, and of 139 dB SPL by 0.22 inch rifle with envelope (20 dB from peak) of 3.5 ms in the open, but 140 ms in indoor range.

(a) Assessment of impairment, disability, and handicap: (i) ‘Normal hearing is difficult to define in terms of either normal function or lack of perceived disability, especially as any definition is essentially arbitrary and may be ambiguous as to whether or not “normal for age” is intended’ (at p. 81); (ii) standards for various occupations cited, including UK armed services and civil flying; (iii) the authors consider that the armed services’ top grade (an average HTL of no more than 15 dB over 3, 4 and 6 kHz as well as over 0.5, 1 and 2 kHz) for hearing (H1 of PULHEEMS – the classification of medical fitness used by the British armed services) is ‘exceptionally good’; H2, which requires an average HTL not exceeding 28 dB over 0.5, 1 and 2 kHz and 41 dB over 3, 4 and 6 kHz, constitutes ‘acceptable practical hearing for service purposes’ and so constitutes the ‘general entry standard’ (pp. 76–8). (b) Capability of working on account of damaged hearing: ‘There are few jobs in which perfect hearing is essential. A number of jobs can be done even by people with total or profound hearing impairment. For the majority of jobs it is sufficient that the applicant (wearing a hearing aid if appropriate) can hear what people say in the normal working environment and no special tests are therefore needed for pre-employment assessment’ (at p. 70).


Need for independent confirmation of a new theory or observation before its acceptance: ‘The view that replicability is essential in science is widespread’ (at p. 372). This does not contradict the value of the single case report. Such a case report will often trigger off reports of similar cases or, by explanation, can be shown to be integratable into the pattern of general knowledge. Moreover, the single case can be used as its own control when the effect of a particular treatment is being studied. Indeed, the study of the single case is essential when intraindividual variation is the subject of enquiry.


(a) No mention of hazardous occupational noise exposure as cause of Ménière’s disease/endolymphatic hydrops. (b) Existence of cochlear hydrops: ‘Cochlear hydrops without vertigo is an undoubted entity’ (at p. 446).

58 Joint Report of the Royal College of Physicians and the Faculty of Occupational Medicine to the Health and Safety Executive’s Medical Division.
Recognition of a form of endolymphatic hydrops without any associated symptom of dizziness.

Calculating hearing disability from hearing threshold levels at six frequencies – 0.5, 1, 2, 3, 4 and 6 kHz.

(a) The broad problem of noise, particularly its psychological effects, but no mention of tinnitus or hyperacusis:

We have received evidence from many sources; private individuals, local authorities, associations of citizens of various kinds, representatives of industry, specialist and technical bodies. The evidence has ranged from personal complaints to closely reasoned arguments based upon measurable facts affecting many thousands of people. [para. 3] . . . We have given . . . a general summary which refers to effects on health in its widest sense . . . We have also devoted a chapter (Chapter XIII) to a special case – the effects of long-continued intense noise, e.g. in causing industrial deafness [para. 14] . . . Granted that noise causes much annoyance, it might be expected that in many cases mental or nervous illness would result; and this was often suggested to us in our enquiries. Nevertheless, we found very little specific evidence to support this view. [para. 44] . . . It might be expected that annoyance from noise might, in some people, precipitate a mental disturbance or disorder to which they are predisposed. As far as we are aware, the only relevant investigation that has attempted to explore this possibility is that conducted by the United States Navy. Although the results of this investigation were negative, showing no psychological upsets, it should be borne in mind that the crews of aircraft carriers do not provide a typical cross-section of the population [para. 46].

59 Referred to by the Committee as ‘Cochlear Ménière’s disease’, but best referred to as ‘cochlear hydrops’.

60 Fluid accumulation in the inner ear. Frequently referred to as the Wilson Committee as the chairman was Sir Alan Wilson FRS, a physicist.

61 Frequently referred to as the Wilson Committee as the chairman was Sir Alan Wilson FRS, a physicist.

62 The setting up of the Committee was precipitated by complaints of the increasingly disturbing effect of noise to which all and sundry were being exposed.

63 Even though the Committee received evidence from the British Association of the Hard of Hearing, the British Association of Otolaryngologists, the British Medical Association, the Director of the Medical Research Council Research Unit on Deafness, and the Trades Union Congress.
(b) Effects on working efficiency:

50. . . . The problem of whether or not noise has any effect on the performance of tasks has been the subject of investigation, both in the laboratory and in field experiments, for many years. However, the evidence that we have received shows that no general conclusions have yet been reached. 51. Some experiments in industrial situations have shown that a marked improvement in speed of work has occurred when the noise level of the working environment was reduced. However, in some of these experiments the higher rate of work has been maintained when the noise level has been restored to its original value or the workers in the quietened rooms have been moved into rooms in which the noise level has not been reduced. The conclusion to be drawn from these experiments is, therefore, that the improvement in output arose from increased morale resulting from the workers’ realisation that an interest was being taken in their working conditions, and not, directly, from the reduction in noise. [The Hawthorne effect.]

(c) Diverse expertise of the Committee64 and its Assessors65 that would ensure the type of assessment that one would expect of what one would now term an evidence-based society.


Most common location for an earpit: 90% are on front part of helix.


Earpits being an inherited condition, and due to autosomal dominant inheritance – from parent to child – with no gender influence.


Matching Békésy audiograms of claimants to patterns that apply to patients with presumed uncomplicated occupational noise-induced hearing loss.


64 As well as the Chairman, another member of the thirteen-strong Committee was a Fellow of the Royal Society, three others were engineers, and the rest included a barrister, a housewife, a local government officer and a public health physician.

65 Among the nine Assessors there were two senior civil servants, an aeronautical engineer, a mechanical engineer, the head of the Physics section of NPL, a public health physician and a senior doctor from the MRC.
The two criteria for acceptance of a disease as ‘occupational’ and the question that arises as to whether or not the second criterion can now be supported:

Before a disease can be prescribed for the purposes of the Industrial Injuries Act, certain statutory conditions must be satisfied; briefly, the disease must represent a risk of employment rather than a general risk to the population as a whole, and it must be possible to establish the attribution to employment in individual cases.


The increasing problem of noise as an environmental pollutant: ‘Quiet enjoyment is increasingly menaced by intrusive noise.’


Data, in conjunction with Wheeler and Dickson’s Royal Air Force data, on which standard reference zero for the calibration of pure tone air conduction audiometers was originally based. Both studies employed a Standard Telephones and Cables ST&C 4026 earphone and thresholds on each subject were determined with a purpose-built 2 dB step audiometer. The RAF certainly employed an initial hearing test with a conventional 5 dB step audiometer. In both studies the subjects had been rigorously audiologically screened. The NPL, but not the RAF study, measured the threshold of hearing at 6 kHz.


Explaining noise-induced hearing losses from the standpoint of mechanical effects in the middle ear and the cochlea; to the medical man this seems a much more plausible explanation than to claim that noise accentuates the apoptotic (ageing) process.


Noise in the military environment constituting a serious hazard to hearing; hearing damage risk criteria ‘using the (A-weighted) isoenergy principle

66 The Honourable Mr Justice Cusack.
67 Hence operation of a learning factor.
represent the best solution \([L_{\text{Aeq,8}} = 85 \text{ dB(A)}]\) at the present time . . . In military life the soldiers must use all their hearing abilities . . . However, the military acoustic environment is often highly hazardous and is frequently the cause of acoustic trauma.'


The equal energy hypothesis may not be applicable when exposure consists of impact noise.


The concept of, and need for, controls has been recognized for more than 100 years: ‘Four bladders were first tried as a control experiment’ (at p. 413) in studying the way insect-eating plants (specifically, *Utricularia neglecta*) work.


Controls being essentially standards for comparison: ‘whereas 6 radicles without any attached squares, which served as standards of comparison or controls . . .’ in studying the sensitivity of the roots of the pea, *Phaseolus* (at p. 162).


No significant middle ear pathology found in 114 adults with normal tympanograms.


The scientific method: ‘Science is, after all, an interrogation of nature, yielding data that we try to link into a coherent scheme.’


Sensorineural hearing losses other than those due to noise are prevalent in the general population.


Ageing allocation in a hearing disability assessment: ageing produces an increase in hearing disability over and above that which results from the
hearing impairment registered by the pure-tone audiogram although the latter will also include an ageing component; 20 years of ageing is equivalent to a 10 dB deterioration in the threshold of hearing (at p. 114).


(a) The extent of hearing disability in the general population: ‘26% of adults report great difficulty with speech in noise’ (at p. 916). (b) Relative unimportance of occupational noise exposure in affecting the hearing of people in general: ‘the prevalence of hearing impairment is not greatly associated with noise exposure, sex or occupational group, but predominantly with age’ (at p. 917).


(a) ‘It is hoped that this book will be of substantial benefit . . . to those who wish to use the control data presented here to assess the impact of noise or other potentially damaging factors on auditory status’ (at p. ix). (b) ‘Many studies refer for the demonstration of an effect of some external agent (e.g. drugs, noise, disease) to hearing thresholds on inappropriate and out-of-date standards (such as ISO 7029). If sufficient data concerning the age and sex of the case or control group are available . . . it is possible to refer to one of the tables given here to assess whether the purported effect would stand against the typical or screened population data shown here. Generally such comparisons seem to reduce the apparent claimed difference’ (at p. 7). (c) An appropriate set of non-noise-exposed hearing threshold levels to use for comparative purposes, including medicolegal ones (at p. 7), without a specific prohibition, in contrast to the interdictions of other data sets, but air–bone gaps of compared audiograms should be zero. 69 (d) Notching at 6 kHz occurring in thresholds of both male and female, and both manual and non-manual workers who have no impaired sound transmission through the outer or middle ears and have had no hazardous noise exposure. (e) The existence of a socio-economic factor (or factors) affecting hearing after hazardous occupational noise exposure has been excluded. (f) ‘[T]he distribution of hearing threshold in the population is not strictly a “normal” (Gaussian) distribution.’ (at p. 8). (g) Provides data on likely perceived severity of specific hearing disabilities at various hearing threshold levels for different ages (various tables on pp. 898 to 970 inclusive).

68 Essentially the finalized report on the Medical Research Council’s National Study of Hearing.
69 Averaged over 0.5, 1 and 2 kHz.
Hazardous occupational noise exposure is not a tinnitus risk per se: the Medical Research Council’s National Study of Hearing concluded that potentially noise hazardous employment did not constitute a particular risk to the development of tinnitus, but high blood pressure is associated with tinnitus: ‘Significantly increased systolic and diastolic blood pressure is found at all ages for bilateral none-slightly annoying PST (prolonged spontaneous tinnitus) . . . but . . . ‘Age . . . and noise . . . have no role . . .’

What constitutes a hearing disability?

The question of what frequencies ought to be considered and what constitutes a disability has been discussed back and forth in various committees and meetings. The criterion that was accepted in the Committee on Conservation of Hearing was the ability to understand everyday speech adequately. This does not mean monosyllables in the audiometric discrimination test, nor does it mean nonsense syllables in the psychoacoustic laboratory; the concept is everyday speech ‘as she is spoke’, and this implies the value of contextual cues and also the careless way that people speak. There is a great deal of redundancy if we are talking about everyday speech and not about the unexpected message, the unfamiliar proper name or the important telephone number. With this qualification it is not necessary to hear particularly well above 3 kHz if 2 kHz is alright . . . Efforts to show a failure in the understanding of speech by available tests – tests that do not do involve nonsense syllables but real sentence intelligibility – do not show any great impairment for the kind of audiograms under discussion here, even some of those with severe 4 kHz dips . . . and I hold now for continuing with 0.5, 1 and 2 kHz as a realistic measure when one is concerned with sentence intelligibility of familiar material in everyday speech.

Acceptability of Kryter’s 1973 paper: (a) ‘in any comparative study in which a few decibels difference may become critical the control group must be tested in the same way, under the same conditions, and if possible by the same testers as the non-noise exposed group. This is not easy to arrange, any more than it is to find a properly matched control group’. (b) ‘I make a plea to all users of the term “hearing level” to confine that term to the physical output of an audiometer (in decibels above the appropriate
ISO reference level) and to use “hearing threshold level” (HTL) to specify the hearing level which is the threshold of hearing for a particular ear (see ANSI S3.6-1069).


(a) ‘Normal hearing and the threshold of handicap’:

Healthy young adults differ from one another with respect to the sensitivity of their hearing just as they differ with respect to height, weight, blood pressure, basal metabolism and many other anatomical and physiological characteristics . . . This range is generally considered to extend from the least intensity available on an audiometer to about 23 dB [HL (ANSI)]. Hearing threshold levels near either extreme may be considered unusual but not abnormal, although the occurrence of changes of sensitivity within the range of normal may have some diagnostic significance, particularly in children and adolescents. (p. 276)

(b) ‘Normal threshold of hearing’ is a term that should be avoided because of its medical and medicolegal implications. There is no single normal threshold of hearing; there are ranges of normal hearing (at p. 540). (c) ‘Hearing loss’ is a term that should not be used to specify ‘hearing level’ or ‘hearing threshold shift’, which terms should be quantified by a numerical value that itself is specified in ‘decibels’ (at pp. 92, 542):

it is properly used in referring to a general medical condition such as ‘conductive hearing loss’ or ‘a noise-induced hearing loss’. It emphasises the impairment of function. It is illogical and very confusing, however, to speak of a hearing loss of 20 dB (ISO), for example, because this value lies well within the range of normal. It is very difficult to explain this fact to a layman. He automatically thinks of a hearing loss as an impairment and often as a handicap. (at p. 276)

(d) Rules for the evaluation of hearing handicap:71

Ideally, hearing handicap should be evaluated in terms of ability to hear everyday speech under everyday conditions . . . because of present limitations of speech audiometry, the preferred procedure is to estimate the hearing-threshold level for speech from air conduction measurements made with a pure-tone audiometer. For this estimate the Committee on Conservation of Hearing72 recommends the simple average of the hearing-threshold levels (in decibels) at the three frequencies 500, 1000 and 2000 Hz. (at p. 277)

71 Usually referred to as ‘disability’ in the UK and by the WHO.

72 Now the Committee on Hearing and Equilibrium of the AAOO.
(e) To translate ‘ASA-1951’ audiometric data to ISO values the following exact formula may be employed for statistical, research, or special clinical purposes at the discretion of the individual user:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Add</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>6000</th>
<th>8000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>15</td>
<td>14</td>
<td>10</td>
<td>8.5</td>
<td>8.5</td>
<td>6</td>
<td>9.5</td>
<td>11.5</td>
<td></td>
</tr>
</tbody>
</table>

(f) Bone-conduction thresholds of hearing are affected by mechanical factors in middle ear disorders (at p. 93).


5-HT (5-hydroxytryptamine, i.e. serotonin) being involved in sensory reception and stimulus reactivity.


Dignifying ‘first-hand experiences’ by a technical term of their own, viz. qualia.


The need to see, and importance of, medical records. Lord Denning advised doctors to

collect the attendance records made by all the doctors who had examined and treated the patient and all the notes made by the nurses and doctors in every hospital where he was . . . At one time it was thought that these were confidential and could not be disclosed without the consent of the patient himself and the doctors and nurses and hospital concerned. But that notion is gone, because their disclosure is necessary in the interests of justice.


(a) Specific advice to employers on methods for controlling, measuring and recording noise levels, together with advice on hearing protection for workers. (b) Specifying a maximum noise level to which workers should be exposed, namely 90 dB(A).

DEPARTMENT OF HEALTH AND SOCIAL SECURITY (1973) Occupational Deafness. Report by the Industrial Injuries Advisory Council in accordance with Section 62 of the

73 See also Health and Safety Executive (1978).
National Insurance (Industrial Injuries) Act 1965 on the question whether there are degrees of hearing loss due to noise which satisfy the conditions for prescription under the Act. (Cmd. 5461). London: HMSO.

(a) Non-specificity of clinical picture in occupational noise-induced hearing loss: ‘apart from a characteristic pattern on the audiogram showing typically the greatest loss at the 4,000 Hz frequency, there are no signs or symptoms which are specific to noise-induced deafness’ (paragraph 31). (b) There is some confusion in the evidence presented by the British Association of Otolaryngologists regarding the different auditory sensory effects of cochlear hearing losses: ‘the loudness distortion effect which is known as recruitment’ (paragraph 24). (c) Value of Békésy audiometry: ‘would be useful in most cases, (i) to check on manual results, (ii) in case of surprise non-organic type V patterns, (iii) in unexpected cases of excessive tone decay as in a retrocochlear lesion’ (p. 53). (d) ‘Low fence’: ‘only after the hearing loss has risen to about 30 dB or more, depending on frequency, that the subject himself is aware of the deterioration to the point of seeking help’ (paragraph 27), and ‘The British Association of Otolaryngologists suggested that the level of hearing loss appropriate to the requirements of the Industrial Injuries Act would be an average of 40 dB or more over the 1,000, 2,000 and 3,000 Hz frequencies.’ (paragraph 26). (e) The evidence74 presented by the British Association of Otolaryngologists was that tinnitus was not a common feature of noise-induced deafness’ (paragraph 24). Subsequent reviews of the DSS scheme, up to and including Cmd. 1245 of 1990, have not sought to change this statement even though the review committee has considered tinnitus on at least one occasion. (f) There is no recommendation that examiners should use a formula, let alone any specific formula, in the diagnosis of occupational noise-induced hearing loss. (g) Proportion of noise exposed workers affected: ‘from the results of a survey carried out by HM Factory Inspectorate during 1971 . . . it was estimated that from a total workforce of 6½ million people, over 580,000 were exposed continuously to noise at levels of 90 dB(A) or more for all or part of the working day’ (paragraph 17):

We received in evidence widely varying estimates of the likely number of noise-deafened workpeople. In the main these estimates were unsupported but one of our witnesses, Professor G.R.C. Atherley, presented in evidence a paper entitled ‘An estimate of the extent of occupational deafness among the employed population of Great Britain.’ . . . It was estimated that the hearing of approximately 13,000 persons would be severely affected by occupational noise and roughly twice that number would be mildly affected. (paragraph 18)

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74 Prepared by DL Chadwick, RRA Coles, EDD Dickson, PF King and IG Robin.
(h) wide-ranging\textsuperscript{75} in breadth and representativeness of organizations and individuals\textsuperscript{76} that submitted evidence to the Industrial Injuries Advisory Council’s Industrial Diseases Sub-Committee that prepared the report.\textsuperscript{77} (i) Diverse expertise of the IIAC\textsuperscript{78} and its Industrial Diseases Sub-Committee,\textsuperscript{79} which would ensure a correct assessment of the ‘full investigation’ that reflects what one would now term the yardsticks of an evidence-based society.\textsuperscript{80}


(a) Acknowledgement of principal role played by RRA Coles ‘in getting this scheme\textsuperscript{81} off the ground’. Foreword by Chief Medical Adviser (Social Security). (b) Hazardous noise level: ‘21. The limit for continuous exposure to a reasonably steady sound for 8 hours in any one day is that the sound level should not exceed 90 dB(A).’ (c) What constitutes a normal audiogram: ‘41. Interpretation of Audiograms – In interpreting the audiogram it is important to remember that the normal hearing level refers to the average thresholds of normal young persons. The scatter of individual test frequencies is mostly taken as ± 20 dB.’ (d) Learning process in how to do the test: ‘42. There is an initial learning period which leads to improvements of from 1 to 15 dB with manually operated audiometry. A proportion of persons have difficulty with self-recording audiometry and may show learning effects of up to 30dB’.\textsuperscript{82} (e) Recognition that genetic factors can produce an audiometric picture similar to that resulting from occupational noise damage: ‘45. Notches occur in the audiogram of some cases of hereditary hearing loss, chiefly in the 1,000–3,000 Hz regions, in others there is a high tone hearing loss’ (at

\textsuperscript{75} It appeared to include every institution and body that could possibly have contributed to the matter.

\textsuperscript{76} Including (through the TUC’s evidence) those workers in the UK who are exposed to hazardous occupational noise levels.

\textsuperscript{77} In no other country has the appropriate government department consulted so widely and wisely.

\textsuperscript{78} At p. 2.

\textsuperscript{79} At p. 40.

\textsuperscript{80} The UK’s noise exposed workers were represented on both the Council and its subcommittee in the person of Peter Jacques (TUC member) who had started life in the building trade.

\textsuperscript{81} Occupational noise-induced hearing loss as a prescribed occupational disorder.

\textsuperscript{82} This is a very large figure when compared to that (of the order of 1 dB) in other reports; there is no indication of the source.
p. 15). (f) No recommendation that examiners should use a formula, let alone any specific formula, in the diagnosis of occupational noise-induced hearing loss.

DEPARTMENTAL COMMITTEE ON COMPENSATION FOR INDUSTRIAL DISEASES


Official acceptance that ‘boilermakers’ deafness’ was unquestionably a disease due to employment but could not be prescribed under the old Workmen’s Compensation Acts because it did not prevent a man continuing in his employment.

DICKSON EDD (1953) Some effects of intense sound and ultrasound on the ear.84 Proceedings of the Royal Society of Medicine 46: 139–44.

A review of the state of knowledge on occupational noise-induced hearing loss at that time; suggesting an overall sound level of 90 dB(A) as the level at which industrial noise becomes hazardous to hearing.


Tinnitus associated with occupational noise-induced hearing loss: it is to be noted that, having reviewed the literature on occupational noise-induced hearing loss for this textbook on occupational medicine, and incorporating his own experiences and those of the members of his department, mention of occupational noise-induced tinnitus is absent. Mention of noise-induced tinnitus is in respect of gunfire.


(a) Tinnitus and occupational noise-induced hearing loss. There is no mention of tinnitus associated with occupational noise-induced hearing loss. (b) Recognition of the existence of sensorineural hearing losses in people subject to hazardous occupational noise exposure that are not to be attributed to the noise exposure: ‘An occupational injury may develop over a long period of time and in loss of hearing cases aetiology is sometimes obscure’ (at p. 30). ‘I need hardly add that deafness would be barred from compensation unless it could be shown that a perceptive element was due to noise’ (concluding remarks at p. 32).

83 The Samuel Committee.
84 Presidential address to Section of Otology.

Attributing the unsteadiness symptoms of ‘supersonic sickness’ to intense stimulation of vestibular labyrinth with acoustic energy in audible frequency range (not ultrasonic range) – a Tullio effect, but the symptoms are mild and transitory with no permanent ill effects.


An indication of the work already being done at that time in the UK on the effects of noise on hearing.


(a) ‘Supersonic sickness’ to be regarded as a figment of a journalist’s imagination, although transitory and mild symptoms of unsteadiness have been experienced during the running of jet engines on test beds or running up aircraft jet engines on the airfield. There were no permanent ill effects. This is attributable to Tullio phenomenon. Publicity given to the condition has raised the additional problem of the effect on the morale of service personnel engaged in this work. (b) The disinclination of noise-exposed personnel to wear hearing protection:

Use of protection for the ears of ground crews was not popular, mainly because of difficulty of conversation. Thus 1 used cotton wool when the engine was running at high speeds; 5 had employed earplugs sporadically during their careers. The remainder, i.e. 71 ground crew (mainly fitters and flight mechanics), used their fingers to block their ears when the noise was of too great an intensity to be borne without discomfort. (at p. 279)


No correlation was discovered between balancing organ function and hearing threshold level after examining 344 cases of occupational noise-induced hearing loss.


A statistical study, with use of signal detection theory, of annual audiograms of more than 4500 workers in a large manufacturing company in the USA to
show what one can expect in practice from manual audiometry conducted under hearing conservation programmes. (a) It was observed that: (i) ‘an STS, whether due to noise or to aging, has the same impact on the individual, and deserves to be detected and noted’; (ii) this (diagnosis) requires much more than just the individual’s audiometric measurements and a table of age corrections. Family history, general medical history (including drugs, trauma, etc.), sound level measurements, the employee’s detailed work history, and audiometric profile are among the data which must be considered in order to arrive at a diagnosis. For example, a man who has worked in one job for 15 years without STS, is promoted to a supervisory job with less noise exposure, and five years later begins to show progressive hearing loss, is probably not experiencing NIHL.

(b) The study confirmed: (i) definitions of significant threshold shift: those based on threshold averages are superior to those based on single frequencies; (ii) trend (but not attaining statistical significance) for shifts in threshold at each frequency to be greater in the left ear.

(c) The study concluded that: (i) otoscopic reports by the factory nurses, who were the industrial audiometrists, correlated ‘very poorly’ with those of qualified ENT specialists; (ii) industrial audiometry is ‘less reliable’ than clinical audiometry; (iii) ‘pure tone thresholds measured in industry are, on the average, about 5 dB worse than those measured in clinical settings, for the same workers’; (iv) ‘[T]hreshold shifts caused by test–retest variability, in a 1-year comparison, are as large as those caused by noise-induced hearing loss’; (v) ‘Variability is reduced by pure tone averaging’; (vi) ‘Presbyacusis is an important cause of threshold shifts. In this study, ageing effects accounted for half the threshold shift at 4 kHz’; (vii) ‘Significant threshold shift should be defined using pure tone averages. A criterion level of 10 dB for either the 0.5, 1, 2 kHz average or the 3, 4, 6 kHz average in either ear is tentatively proposed, although higher levels may be equally appropriate’; (viii) ‘An apparent STS should be validated by prompt retest’; (ix) ‘A practical consequence of the use of periodic audiometry, regardless of the criterion for STS, will be large numbers of spurious shifts and real, but not noise-induced, shifts. This may have the effect of a de facto lowering of the permissible exposure level to 85 dBA TWA’; (x) ‘A method of evaluating criteria for STS, based on a comparison of proportions of positive and negative shifts for each proposed rule, and the construction of ROC curves, has been presented.’


(a) How the USA settled on what was a hazardous occupational noise level. The US government body that has dominated the scene regarding
what is, or is not, a ‘reasonable safe place’ is the US Department of Labor’s Occupational Safety and Health Administration (OSHA), which is analogous to, for example, the British Health and Safety Commission. The American Occupational Safety and Health Act has the same role as, for example, the British Health and Safety at Work Act. Jayne\textsuperscript{85} recounts the intriguing interplay\textsuperscript{86} between OSHA and other US government bodies\textsuperscript{87} as they searched for an acceptable level of safe working. This culminated in the conclusion that the 90 dB(A) eight-hour exposure is ‘a highly satisfactory criterion to determine the need for a hearing conservation program’.\textsuperscript{88} The 85 dB(A) eight-hour exposure forms an appropriate ‘action level for hearing conservation, and there is no rational reason to consider a higher or lower level.’ These conclusions are coincident with those of ISO-1999,\textsuperscript{89} which predicts no statistically significant risk of \textit{material impairment} (see later) at exposures of 85 dB(A). ISO-1999 gives information on the \textit{proportion} of excess hearing threshold shifts that can be expected in a population subject to a given noise exposure. Although endorsed by the USA, this international standard has not yet been endorsed by the UK. Paradoxically, Congress sought to limit the use of the Occupational Safety and Health Act in what would amount to common law actions. This non-applicability of the Act has been upheld in civil actions, for example under the Federal Employee Liability Act\textsuperscript{90} and in product liability cases.\textsuperscript{91}

(b) Intermittency of the hazardous occupational noise exposure: Data relating noise-induced permanent threshold shifts to hazardous occupational noise exposure

are based entirely on studies of workers who had essentially continuous workday noise exposure (other than lunch and breaks). Exposures for less than eight hours a day are of course less hazardous, but how much less hazardous? Since a 3-dB change in intensity corresponds to a doubling (or halving) of the rate of sound energy flow, an eight-hour exposure of 90 dB(A) delivers as much sound energy as four hours at 93 dB(A), or two hours at 96 dB(A). The equal-energy principle predicts that each of

\textsuperscript{85} The lawyer who contributed a chapter to Dobie’s book.
\textsuperscript{86} Including how the conclusions of one committee were ‘materially changed’ when its composition changed (at p. 234).
\textsuperscript{87} For example, EPA (Environmental Protection Agency) and NIOSH (National Institute for Occupational Safety and Health).
\textsuperscript{90} \textit{Ries v National RR Passenger Corp.}, 960 F.2d 1156, 1162 (3rd Cr. 1992).
\textsuperscript{91} \textit{Bailey v V & O Press Co.}, 77 F.2d 601 (6th Cir. 1985).
these exposures carries equal risk. There is considerable evidence that brief exposures, when made intermittent, are less hazardous than longer exposures of equal energy, probably because some recovery occurs in the ‘noise-off’ periods . . . These relationships are complex . . . OSHA (1983) has attempted to correct for this by using a 5-dB trading ratio instead of the 3-dB ratio recommended by ISO-1999. (at p. 147)

(c) Susceptibility to occupational noise-induced hearing loss in workers with hand-arm vibration syndrome [HAVS]: ‘Most of the effects found in these studies were small, and the data are too scanty to permit estimations of either the threshold or magnitude of hazard’ (at p. 151). (d) Degree to which need to raise voice as guide to noise levels: ‘As background noise levels rise, listeners have increasing difficulty understanding speech . . . Speakers automatically compensate by raising their voices . . . At a one-meter conversational distance, shouting is necessary in background levels above 80 to 85 dBA, and even shouted conversations are inadequate above 95 to 100 dBA’ (at p. 156). (e) Regarding distinguishing between ‘ability’ and ‘disability’: ‘Clearly, ability that is merely below average does not constitute a disability’ (at p. 110). (f) The ‘low fence’ adopted by medical examiners in the USA is that of the American Academy of Otolaryngology (AAO) 1979 rule, namely 25 dB HTL (average for frequencies 0.5, 1, 2 and 3 kHz, and with a weighting of 5:1 in favour of the better ear): ‘the AAO-1979 method is more widely used in the United States than any other, and is well justified . . . All of these methods use a 5:1 weighting favoring the better ear, and a 25 dB low fence.’ (g) The distinction between ‘material’ and ‘not material’ impairment:

The American Academy of Otolaryngology . . . in its Guide for the Evaluation of Hearing Handicap (what would be termed ‘disability’ in the UK) states that handicap begins at 25 dB HL (for average threshold in the speech frequencies). Thus these definitions imply that impairment (AAO 1979) begins at 15 dB HL, where hearing levels begin to be abnormal (for young adults); that between 15 and 25 dB HL the impairment is not ‘material’; and that above 25 dB HL (for the speech frequencies) there is both material impairment and handicap. (at p. 88)

(h) Patients who have hearing impairment only at very high frequencies (≥ 6 kHz) do not report speech communication problems (at p. 90). (i) Commentary on ‘Black Book’. In dealing with an individual’s exposure to occupational noise at different levels, failure to incorporate the ‘pre-emptive’ effect of prior high-level exposures on subsequent low level exposures. ‘The most important flaw in this method’ (at p. 300). (j) No mention of hyperacusis. (k) ‘Nonoccupational noise sources . . . shooting’: (i) ‘Guns are the main source of hazardous impulse noise. Although .22 caliber weapons usually deliver less than 140 dB peak sound pressure to
the shooter’s ears, shotguns . . . frequently deliver up to 170 dB . . . These impulses can cause either acoustic trauma (sudden and permanent threshold shift) or NIHL (with TTS that initially recovers, and eventually becomes permanent after repeated exposures)’ (at p. 166); (ii) risk relative to occupational noise: ‘. . . it seems likely that for many workers in industry, hunting and target shooting are more important causes of hearing loss than their work environments’ (at p. 167); (iii) asymmetry: ‘In the medical-legal setting, asymmetry argues in favor of a contribution of gunfire to an individual’s NIHL, and lack of asymmetry against such a contribution, but neither of these is absolute’ (at p. 167). (I) Extreme hearing losses:

ISO 1999 purports to be valid only within the fifth and ninety-fifth percentiles . . . otologists will fairly frequently encounter patients with audiograms worse than the appropriate ninety-fifth percentile curves . . . who have no apparent etiology for their hearing loss other than ARHL and NIHL. Several possibilities must be considered. Most obviously, such persons may be very highly susceptible to noise, aging, or both. However, most otologists, including the author, believe that NIHL is never profound; excluding acoustic trauma, thresholds rarely if ever exceed 60 dB for PTA-5123 . . . The natural conclusion is that the more extreme the severity of the hearing loss, the less likely it is that NIHL made a significant contribution. (at p. 285)


(a) Prevalence of non-occupational hearing disorders in workers with hazardous occupational noise exposure: half of the workers picked up in industrial hearing monitoring have hearing disorders that are not attributable to hazardous occupational noise exposure. (b) There is no mention of ‘industrial sudden deafness’.


Admissibility of epidemiological evidence: ‘Moreover, the courts have made it clear that reports of epidemiological studies are not of themselves admissible evidence of the facts on risk reported in them (see H v Schering Chemicals Ltd92), although they can be introduced into evidence through expert testimony’ (at p. 363).


(a) Different frequencies to which tinnitus is matched, depending on the nature of the hearing disorder, viz. over the whole frequency range in

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normal hearing and in perceptive deafness (unknown cause) cases, predominantly 2 kHz to 8 kHz in presbyacusis, 125 Hz to 500 Hz in Ménière’s disease, 250 Hz to 2 kHz in middle ear disease, 500 Hz to 4 kHz in otosclerosis, 2 kHz to 8 kHz in acoustic trauma. (b) An ordinary (manual) clinical audiometer is adequate for these purposes.


Undesirability of changing a standard, or any other yardstick:

The Measure of Westminster was a standard established by Edgar, King of England, in the tenth century. About two hundred years later Henry I had a yard standard made from the length of his arm, to prevent the fraudulent measuring of cloth. In the fifteenth century Henry VII revised the yard yet again, making it the length of his arm – a modest 34 inches (86.3 cm). Then Elizabeth I came along and – not to be outdone by a mere short-armed man – had an extra couple of inches welded on in her name. (at p. 42)

The associated television programme added that Queen Elizabeth also said that that would be the final, non-changing, standard. Clearly she had the sense to realize that long-term changes in some measurable quantity would not be possible if the yardstick was continually changing; thus right or wrong, there are cogent arguments for not changing a standard.


Pattern recognition as the way of diagnosis:

But eventually, after many discouraging moments, it all begins to click. Then that marvellous gift of pattern recognition kicks in, so that we can tell a lime tree from a distance, a poplar from a moving train, effortlessly, without having to make out the details, just as we recognise a familiar face, a patient with Graves’ disease, a person with cirrhosis, or now all too often the wasted face of a patient with AIDS. It all takes time, patience, perseverance, and ultimately experience, which is why it takes so long to become a specialist in any field.


Threshold asymmetry: also occurs for the higher frequencies in boys aged 5 to 14 years, so asymmetry cannot always be attributed to either shooting or hazardous occupational noise exposure.

How doctors handle uncertainty in diagnosis: ‘The evidence presented shows that physicians do not manage uncertainty very well, that many physicians make major errors in probabilistic reasoning, and that these errors threaten the quality of medical care’ (at p. 249).


Admissibility of evidence: (a) Regarding facts: ‘Unfortunately, judges do not always remember that all that is necessary to qualify evidence for admission is that it should increase or diminish the probability of the existence of a fact in issue’ (at p. 83). (b) Regarding the personal position of a witness: ‘English law . . . allows the opponent to ask questions of a witness with a view to showing that his past behaviour93 has been such that he should not be believed’ (at p. 75).


How doctors go about making decisions, including those of diagnosis:

The team of an experienced clinical surgeon and an equally trained cognitive psychologist makes a strong case for pattern recognition . . . As one who has spent more than a decade exploring and advocating use of hypothetico-deductive reasoning in surgical teaching, how do I evaluate this contrarian approach . . . I suggest that algorithms and the logic process using Bayesian theory to revise one’s prior probabilities are the ways we solve most simple clinical problems, while some variation of pattern recognition is the intuitive approach we turn to when information overload causes mental gridlock in seeking an answer . . . The case studies in this book are analogous to those used for half a century in law and business schools.


Considerable interindividual differences in loudness perception – so need to determine individual loudness function for each individual claimant if loudness of bis tinnitus needs to be known.


Steven’s power function as expression of the psychophysical law.94

After a hundred years of almost general acceptance . . . Fechner’s logarithmic law was replaced by the power law. The amount of experimental work performed in the

93 Or statements.
94 The subjective magnitude of some physical dimension, for example the loudness of sound, is a power function of its physical ‘strength’.
1950s on this problem . . . was enormous . . . The power law was verified again and again, in literally hundreds of experiments. As an experimental fact, the power law is established beyond any reasonable doubt, possibly more firmly established than anything else in psychology.


Workers exposed to noise levels around 86 dB(A) are no more likely to have abnormal audiograms than those working in non-noisy workplaces; moreover, none of the abnormal audiograms in the ‘noise-exposed’ group were attributable to noise damage to the hearing.


The concept that the adverse effect of noise on the threshold of hearing was a function of the amount of energy in daily exposures to noises above a certain level – the equal energy concept that was to be adopted by the US Air Force in AFR 160-3 and, subsequently, National Physical Laboratory in the noise immission level concept.


Removal of hearing protectors for very short periods during noise exposure seriously reduces the protection (defined as the reduction in equivalent sound level afforded by the wearing of hearing protectors) afforded by them. For example, no hearing protector can provide more than 6 dB of protection if it is worn for less than 75% of the hazardous noise exposure duration. If protectors with an effective attenuation of 30 dB(A) are worn in a working environment of 115 dB(A) the sound level will be reduced to 85 dB(A), but if the worker fails to wear them for only two five-minute periods during the eight-hour working day, the equivalent continuous sound level for that day will be 98 dB(A).


Applicability of Gauss’s law of errors to biological (and, specifically, hearing) data. (a):

This law states that if repeated measures are made on the same physical object, the distribution of the random component on the errors can be well approximated by the Gaussian, or normal, distribution. This law implies that repeated measurements of the length of the same desk would follow the same distribution; but the law certainly does not imply that measurements of the lengths of all of the different desks to be found in
a medical school would do so. The law applies to repeated measurements of one’s own height, but the difference between that height and that of one’s neighbor is something quite different from a random error of measurement. (at p. 69)

(b) ‘Even today, regrettably, many medical students graduate from their medical schools firmly convinced that if a sample is large enough, the distribution will be “normal”, regardless of the measurement under study, and that 95% of the measurements will be included in $x \pm 2\sigma$ . . . The experimental fact is that for most physiological variables the distribution is smooth, unimodal, and skewed, and that $x \pm 2\sigma$ does not cut off the desired central 95%’. (c) ‘We have no mathematical, statistical, or other theorems that enable us to predict the shape of the distributions of physiological measurements’. (d) ‘We propose that the phrase “normal limits” be dropped, and that the phrase “clinical limits” be used to refer to the $2^{1/2}$ and $97^{1/2}$ percentage points to the distribution of healthy persons’. (e) ‘Granted, clinical judgment is essential to the care of every patient. Nevertheless, since it may be based in part upon incomplete or biased recall, with the risk that anecdotes or special cases may carry more weight than general medical experience or the usual case, clinical judgment may be particularly unsuited to the interpretation of quantitative data’ (at p. 75).


Twelve per cent of patients with Ménière’s disease show a falling audiogram, a high frequency sensorineural hearing loss.


The authors relate the degree of annoyance occasioned by domestic appliances on a scale of 1 to 5; the scale grows roughly in 10 dB steps from 55 dB to 93 dB, with the verbal descriptors of ‘not’, ‘slightly’, ‘moderately’, ‘quite’ and ‘extremely’ annoying.

95 Or, by implication, hearing.
96 Endolymphatic hydrops associated with both dizzy and hearing symptoms.
97 Thus, if, for the purpose of calculating the decrease in the proclivity of noises to annoy a man with ONIHL, we consider the hearing threshold levels of 1, 2, 3 and 4 kHz to be the relevant factor, then noises which previously would have been ranked as ‘extremely’ or ‘quite’ annoying may have now become ‘moderately’ or ‘slightly’ annoying respectively, and noises that previously would have been ‘moderately’ or ‘slightly’ annoying would now become not so; however, because of the phenomenon of loudness recruitment, the reduction in annoyance rating of noises that would still be heard would not be so marked; but this reduction would itself be offset by the raised noise tolerance of noise-exposed workers.

A study of 115 shipyard workers. (a) It is necessary to subtract 2.5 dB from manual thresholds before comparing these with Békésy sweep frequency audiometric thresholds (at p. 424). (b) Even then the Békésy thresholds appear to be slightly better98 than manual thresholds and by an amount that depends on hearing threshold level and, at least over the range 3 kHz to 6 kHz, on frequency too, with a maximum difference of 7 dB at 6 kHz. At other frequencies the difference appears to be about 2 dB (Table VI on p. 425). (c) Allowance for different types of earphones: ‘The use of different types of Telephonics earphones should be corrected for’ (at p. 428).


Poorer thresholds of hearing in workers who wear earmuffs than in those who wear plugs, probably because the muffs, which give 10–15 dB greater attenuation of sound, are removed more frequently than the plugs.


Genetic predisposition to age-related hearing loss associated with susceptibility to noise-induced hearing loss.


Patterns of speech audiograms in different auditory disorders.


Socio-economic factors: ‘Factors in the social environment, external to the health care system, exert a major and potentially modifiable influence on the health of populations, through biological channels that are just now beginning to be understood.’

98 Except at 500 Hz, where they are about 2 dB poorer.
99 Produced under auspices of Population Health Programme of Canadian Institute for Advanced Research.

The new approach to medical practice:

A new paradigm for medical practice is emerging. Evidence-based medicine de-emphasises intuition, unsystematic clinical experience, and pathophysiologic rationale as sufficient grounds for clinical decision making and stresses the examination of evidence from clinical research. Evidence-based medicine requires new skills of the physician, including efficient literature searching . . . We will refer to this process as the critical appraisal exercise100 . . . A sound understanding of pathophysiology is necessary to interpret and apply the results of clinical research.


One of earliest studies in the UK of temporary effects of noise on hearing.


(a) How common are earpits? Present in about 1% of the population. (b) Prevalence is dependent on criteria for existence – adopting a ‘low fence’: ‘Dimples and depressions (which occur with considerable frequency on the external ear) were called sinuses and included in the series only when deep enough to engage the tip of a probe’ (but no criteria given for ‘engaging’ and no specification for the probe). (c) The majority (about two-thirds) of affected individuals are unaware of presence of the pits. (d) At the time when Ewing did his study earpits were still not considered by specialists to be of any clinical significance:102 ‘The condition is of little practical significance to the clinician’ (study was based upon screening recruits for the Royal Navy).


The Group produced the Irish Hearing Disability Assessment System. This was expressly approved in the High Court in Dublin by Mr Justice Lavan in

100 It is this that distinguishes the clinical opinion per se to which Popper (1972) objected and the clinical opinion that is sought in modern evidence-based medicine.
101 A study based upon screening recruits for the Royal Navy.
102 Despite acknowledging Sir James Paget’s 1878 paper associating such anatomical anomalies with impaired hearing.
103 Comprising nine members (a Director of Public Health, who acted as chairperson, a Director of Occupational Medical Services, a representative of the Department of Health & Children, an audiological scientist, and five otolaryngologists) who had been appointed by the Government of Éire.
104 The so-called Green Book.
Greene v MoD 1998, the High Court Dublin, 3 June, http://www.irlgov.ie/defence/fg2.htm. The system takes the hearing threshold levels at 0.5, 1, 2, and 4 kHz and a low fence of 20 dB HTL to give an ‘average hearing loss’ for each ear, which is then multiplied by 1.25%. A binaural percentage hearing disability is derived after a 4:1 weighting in favour of the better ear. In the cited case the judge awarded a 56-year-old man with 35 years of service and a hearing disability assessed at 2%, £3000.


Requiring a sufficient deviation from average scores before an individual is recognized as being different clinically from normal: for example, an individual will score a positive value on a neuroticism scale but will not be recognized as being neurotic until the score attains a certain value.


There is a difference between presenting expert evidence and presenting a scientific paper: ‘In a court of law, witnesses are required to tell “the truth, the whole truth and nothing but the truth.” This is not the case in a technical seminar . . . The whole truth is not necessary.’


Differences in mean hearing threshold levels measured by seven different trained manual audiometer operators (audiometricians) on otologically normal young adults and for the range 0.5 kHz to 6 kHz: range of these means varied from 6.3 dB at 2 kHz to 10.7 dB at 6 kHz (but not the same subsamples).


Coherence or systematic structure as a criterion of science: ‘a well connected account of the facts is what we seek in science’ (at p. 12).


Approach to clinical diagnosis: ‘Basis for clinical medicine is accurate and coherent amassing of empirical fact.’


Hearing status of pneumatic drill operators: (a) Only two out of nine men experienced any difficulty in hearing speech. (b) Two of the nine subjects
had unilateral hearing loss attributable to causes other than noise. (c) The
test probably overestimated effect of drill noise because there was only ‘an
interval of a few minutes between the end of drilling and the test’ so that
measured hearing threshold levels would be contaminated by noise-
induced temporary threshold shift. (d) Tinnitus

was experienced by only three men. One of them (H) was drilling only two weeks.
He noticed a rushing noise in his ears the evening after the first day of work. This
disappeared and he did not experience it again. Another man (F) reported that in a
quiet room, after drilling, he had a buzzing in his ears. He worked with drills for ten
years. The third one (A), who was drilling for seven months, said that only when
working in a team of several drillers he had a rushing noise in both ears after work.
This usually disappeared after a night’s rest.

Thus tinnitus does not appear to be a problem with pneumatic drill
operators.

FISCH L (1981) Syndromes associated with hearing loss. In Beagley HA (ed.) Audiology and

Importance of recognizing syndromes:

The knowledge and recognition of syndromes with hearing impairment as part of
the clinical picture is important to all workers in audiological medicine. It helps not
only with early detection of hearing loss but also with its diagnosis and prognosis . . .
The discovery of the connections between the defective hearing system and other
disorders can lead to a better understanding of causation of deafness. (at p. 595)

FISCH U (1972) Degenerative changes of the arterial vessels of the internal auditory meatus

A circulatory factor affecting the ear with increasing age: ‘Degenerative
changes are observed histologically in the walls of the arterial vessels
following the first decade of life in man’ (first sentence of Abstract).

FITCH N, LINDSAY JR, SROLOVITZ H (1976) The temporal bone in the preauricular pit,
cervical fistula, hearing loss syndrome. Annals of Otology, Rhinology and Laryngology 85:
268–75.

Structural basis for impaired hearing in BOR syndrome. Pathological
examination of an infant who had died 4 hours after birth – both outer,
middle and inner ears were abnormal and there were extensive other
organ abnormalities. A reduction in the number of sensory nerve elements
(spiral ganglion cells and peripheral nerve fibres) is held to explain
sensorineural hearing loss in the syndrome, but artefactual changes
(‘postmortem autolysis was marked throughout’) limit interpretations.

Interactive effects of ageing, hearing loss, and stimulus complexity on discriminating duration changes in simple sounds. Elderly listeners performed worse than younger listeners in nearly all stimulus conditions. The effects of stimulus complexity on discrimination were greatest among elderly listeners. Hearing loss had no systematic effect on discrimination performance.


The various aspects of auditory temporal (time) processing – for example, temporal resolution, duration discrimination, sequential processing of complex stimulus patterns, which are impaired in elderly listeners, are unaffected by the presence of age-related hearing loss. The consequences of ageing on auditory temporal processing are correlated with the complexity of stimulation and the difficulty of the listening tasks.


The first work on assessing speech hearing ability from pure-tone audiograms.


An example of hyperacusis\textsuperscript{105} in a well-known figure (Noel Coward). After spending just 158 days in the 28 (Artists) Battalion London Regiment, following being called up in March 1918, the actor received a medical discharge together with a payment\textsuperscript{106} of 8s 3d for 13 weeks. He had been admitted to hospital in Colchester just eight weeks after arriving at a training camp. The public records, which have just been released, reported that, in August 1918, he ‘Looks pale, shaky and nervy. Cannot stand any noises and complains of constant headaches. Tremors of both hands plus superficial reflexes. Mental emotional and unstable. Family history bad.’ The actor had apparently told officers that when he was nine years old he had been knocked down by a bicycle and concussed and since then he had suffered from headaches, vertigo, and nervous debility.

This case history illustrates a number of features of the condition of hyperacusis:

\textsuperscript{105} Although this technical term appeared nowhere in the article.

\textsuperscript{106} This is the term used in \textit{The Times}, not `pension`.
• the condition has been recognized by medical examiners in this
country for at least 80 years;
• there are psychological facets;
• the symptom could be attributed to factors other than those relating to
a specific disease of the ear or to prior hazardous noise exposure;\textsuperscript{107}
• however, the condition could be sufficiently disabling to necessitate a
change of employment, but to one that was not necessarily less
remunerative or less socially acceptable;\textsuperscript{108}
• indeed, although it can be disabling it is not necessarily handicapping,
in the sense of not limiting or preventing role fulfilment;\textsuperscript{109}
• it could be sufficiently disabling to be compensable;
• it could have a good prognosis,\textsuperscript{110} even in a severe case such as this and
even (apparently) without specific treatment;
• medical examiners could be wrong in their prognosis;\textsuperscript{111}
• the future course of hyperacusis could be compatible with tolerating,
one might say even enjoying, considerable levels of social noise.\textsuperscript{112}

It is now recognised that loudness tolerance can be reduced by anxiety.
Moreover, there is reduction of sound and light tolerance in headache-
prone individuals. Developments in modern molecular biological
medicine are demonstrating that even our psychology is determined by
our chemistry: 5-HT (5-hydroxytryptamine, i.e. serotonin) has a role in the
control of anxiety and is altered in depression. Moreover, 5-HT is involved
in sensory reception and stimulus reactivity, reducing response to painful
stimulation among other roles, so it is conceivable that a type of hyperacusis
could be due to a 5-HT dysfunction. Noel Coward’s hyperacusis
would fit in with this picture if it could not be attributed to the head injury
many years previously. His hyperacusis would appear not to have been
permanent. It cannot be said that this actor’s symptoms indicated a lack of
patriotism since the latter was amply demonstrated by his \textit{Cavalcade}
1931, \textit{This Happy Breed} 1942 and \textit{Brief Encounter} 1944.

\textsuperscript{107} There is no reason to believe that the actor had ever been exposed to hazardous
noise levels of any type.
\textsuperscript{108} The patient came to be accepted in the \textit{entourage} of the British Royal Family.
\textsuperscript{109} His first play had been performed in the year prior to entering the Army although
the public records suggest that he had been suffering from hyperacusis even at that
time.
\textsuperscript{110} The actor lived to the age of 74. His public life was eminently successful, being
recognized by the knighthood conferred on him in 1970.
\textsuperscript{111} The Medical Board agreed that the actor’s disability was permanent.
\textsuperscript{112} After the Second World War, the actor became a cabaret entertainer in \textit{Café de Paris}
and in \textit{Las Vegas}. 

Noise levels to which military personnel are exposed. There is a peak noise level of 161 dB at the right ear of a firer of 7.62 mm FN rifle. There is a peak noise level of 185 dB at the ear of the firer of a Carl Gustav 84 mm medium anti-tank weapon. It is from 166 dB to 179 dB at the crew positions around the M 109 155 mm self-propelled howitzer, and sound levels of 115 dB(A) are experienced in the passenger section of the M113-A1 armoured personnel carrier, and of 110 dB(A) in that of the CH-147 Chinook medium transport helicopter.


Canadian Forces Hearing Standards: top category (H1) permits a hearing threshold level of up to 30 dB for the frequencies 500 Hz to 6 kHz in each ear.


Familial association of earpits and a sensorineural hearing loss: (a) Pattern of hearing loss: no audiograms published but ‘Cases studied by Miss E Hadfield at the Radcliffe Infirmary’114 were shown to have a perceptive deafness;115 their audiograms showed that both high and low tones were involved, but usually the high tones more than the low’116 (at p. 1355). (b) Severity of hearing loss: ‘The deafness varied from mild to severe’ (at p. 1355). (c) Time course of hearing loss: ‘In some it had been recognised from childhood, others were quite certain that they had been able to hear perfectly until they were about 20 years old, when their hearing had begun to deteriorate’117 (at p. 1355).


113 A report from Cardiff Royal Infirmary and the Department of Experimental Medicine, Cambridge University.

114 That is, in Oxford University’s Otolaryngology Department.

115 This would now be termed a ‘sensorineural hearing loss’.

116 That is, of a pattern that could be compatible with that of occupational noise-induced hearing loss.

117 So this family could well have a syndrome that is different from that of the usual ‘deafness-earpits syndrome’ where the hearing loss usually dates from birth.
A collaborative study between Edinburgh and Glasgow Universities that showed a strong association between blood viscosity and arterial pressure that was independent of many possible confounding factors. Thus for the first time a strong link was demonstrated between blood pressure and sensorineural hearing loss via blood viscosity.


‘A doctor referred a patient . . . to my clinic . . . she had attended an eye hospital for “conjunctivitis” and an ear, nose and throat hospital for “Ménière’s disease” . . . She died some months later, due to a huge acoustic neuroma’ (at p. 60). Thus to reach the correct diagnosis it is not enough for the patient to say that he or she has consulted a specialist or attended a specialist department or hospital. The patient must be properly investigated.


(a) Procedural changes in civil litigation following on Lord Woolf’s report that will affect the way medicolegal reports are prepared: (i) new rules specifically state that the duty of an expert to help the court on matters within his expertise overrides any obligation to the person from whom he has received instructions or by whom he has been paid; (ii) the expert’s report must also be verified by a statement of truth in the form: ‘I believe that the facts I have stated in this report are true and that the opinions I have expressed are correct.’ Proceedings for contempt of court could be brought against someone making a false statement of truth, without an honest belief in its truth; (iii) there is provision for the court to select an expert to provide a report and to direct that the expert selected shall be a single joint expert. In this case, each of the parties may give instructions to one and the same expert;¹¹⁸ (iv) courts may well be more prepared in future to direct a discussion between experts in an effort to reach agreement;¹¹⁹ (v) there is a subdivision into ‘fast track’ cases (where courts will not normally require an expert to attend a court hearing) and ‘multi-track’ cases (where the claim is greater than £15 000 and/or the case is complex).

(b) There is a need for examiners to consider what may be a multiplicity of causative factors and their differential diagnosis and not fall into the logical error post hoc ergo propter hoc: ‘some consultants always manage to find

¹¹⁸ One of this volume’s authors has already received instructions from both parties to an action to provide one and the same report to both parties.

¹¹⁹ This, again, is already happening.
some noise induced hearing loss; others always manage to find some other
cause for the loss’ (the author, a QC, specializes in personal injury litigation
and has a particular interest in occupational disease and injury).

**FRAMPTON MC, COUNTER RT** (1989) A comparison of self recording audiometry in naval
establishments and clinical audiometry in a hospital setting. Journal of the Royal Naval
Medical Service 75: 99–104.

The value of self-recording audiometry. Following the introduction of self-
recording audiometers into regular use in non-hospital Royal Naval
medical facilities, there has been an increase in the rate of detection of
hearing losses and consequent referral for formal audiometry and ENT
evaluation at Naval Hospitals. Forty-two sets of audiograms have been
examined and the hearing thresholds obtained by the two methods
compared. The value of self-recording audiometry, even in the often-
imperfect audiometric conditions available in a Naval sick bay, has been
confirmed and the midpoint of the tracing established as a reliable
indicator of the hearing threshold.

**FRASER FC** (1990) Foreword to Gorlin RJ, Cohen MM, Levin LS (eds) Syndromes of the

Increasing appreciation of the importance of syndromes.

Syndromologists, medical geneticists, and (even more so) other health workers have
found it increasingly difficult to keep up with the vigorous growth of knowledge
about syndromes. The distinguished teratologist Josef Warkany wrote ‘with
increasing interest in congenital malformations a syndrome fever is spreading
through many specialties, and it is difficult for editors of medical journals and
readers to separate spurious from durable and meaningful syndromes.’ That was in
1971 . . . Thus, there is a need for judicious sifting, organizing, and synthesis of the
plethora of syndromic literature into meaningful patterns. The first edition of this
volume was welcomed by those who even then were beginning to feel this need . . .
In the present edition, the breadth and depth of the syndrome data base have been
further extended by the otolaryngologic knowledge of L. Stefan Levin and by specific
chapters from no fewer than 18 collaborators. The result is a truly encyclopedic
work, containing descriptions . . . of nearly 700 syndromes.

Hopkins University Press.

(a) Genetic causes accounted for 50.2% cases – these were cases where
 genetic causation was more likely than not. (b) ‘Deafness-earpits
 syndrome’:

The nature of the deafness in this condition has not been well defined and seems to
vary from family to family. It may be conductive, perceptive, or mixed in character,
and attempts have been made to define heterogeneity in this group on these grounds. However, as in all complex malformation syndromes, the penetrance of each component is variable, and it seems at least possible that the same basic genetic entity is involved in all these families. (at p. 138)


Effect on speech intelligibility of filtering off various frequencies.


Arguments of the legal school supporting use of statistics (Bayesian). Bayesian theory can provide the proper framework for analysing evidentiary problems (at p. 271).


Importance of pathology in the scientific basis of otolaryngology.


(a) Effect of new rules and procedures which will now affect an expert: (i) clinical experts will increasingly be appointed, not by one side or the other, but jointly; (ii) contents of reports will be standardized, leading to lengthier, well referenced, logical reports:

   clinicians will now have to set out not only their own professional views, but also those of any other ‘relevant recognized body of opinion’. This is likely to make the writing of medicolegal reports a lengthier and more demanding process, especially in view of the fact that the courts now expect reports to be well referenced and logical.

We are referred to the case of *Bolitho (Deceased) v City and Hackney HA* [1998] AC 232; (iii) expert evidence will only be received by the courts if it is reasonably required to resolve the issues. (iv) Limitations will be set on expert’s fees. (b) Experts are advised to download the relevant rules and directions from a web site whose address he gives (it is the Lord Chancellor’s). Difficulties may be encountered in accessing this site, but there should be no difficulties with http://www.davidmarshall.co.uk/cpr.html.

\(^{120}\) Quoted by Aitken (1997).
Industrial noise exposure. (a) Correlation between mean exposure time and age was found to be 0.967. (b) Pattern of change: ‘Most hearing level changes at 3000, 4000, and 6000 cps occur in the initial 15 years, whereas at 500, 1000, and 2000 cps, hearing level change is approximately linear with exposure time’ (Abstract). (c) Individual differences: ‘Large individual differences in the amount of hearing level change are evident; these differences increase with audiometric frequency’ (Abstract). (d) Non-additivity of noise and age effects:

hearing level changes produced by noise exposure and hearing level changes produced by aging are not simply additive processes . . . Both curves begin at a common origin, grow towards some point of maximum separation (about 15 years of exposure time or 36 years of age) and then, for increasing age, the curve for the non-noise-exposed men approaches the curve for the noise-exposed men . . . a correction would suggest that hearing improves with increased exposure time beyond about 15 years. (at p. 240)

(e) Distinguishing noise changes from age changes: ‘may not be differentiable’ (Abstract).

Possibility of professional people distorting their own or other observations:

Politicians, real-estate agents, used-car salesmen, and advertising copy-writers are expected to stretch facts in self-serving directions, but scientists who falsify their results are regarded by their peers as committing an inexcusable crime. Yet the sad fact is that the history of science swarms with cases of outright fakery and instances of scientists who unconsciously distorted their work by seeing it through lenses of passionately held beliefs. Gregor Johann Mendel, whose experiments with garden peas first revealed the basic laws of heredity, was such a hero of modern science that scientists in the thirties were shocked to learn that this pious monk probably doctored his data. RA Fisher, a famous British statistician, checked Mendel’s reports carefully. The odds, he concluded, are about 10 000 to 1 that Mendel gave an inaccurate account of his experiments . . . Perhaps he was guilty only of ‘wishful seeing’ when he classified and counted his talls and dwarfs.


121 Also quoted by the Merton Professor of English at Oxford University (John Carey) in The Faber Book of Science, 1995.
Noise level measurements on a total of 593 aircraft. (a) Inside aircraft noise levels during flight: (i) the average inside the cockpit for tail-mounted turbojet/fan-powered aircraft was 85.5 dB(A); (ii) inside all fixed-wing aircraft it was 95 dB(A); (iii) inside single-rotor turbine helicopters it was 97.6 dB(A); (iv) inside single-rotor reciprocating engine powered helicopters it was 101.8 dB(A); (v) inside dual-rotor reciprocating or turbine powered helicopters it was 105 dB(A). (b) There is an additional hazard of the acoustic communication system: ‘acoustic signals and extraneous background noises associated with communication systems must also be considered a potential threat to the hearing of many flyers’ (at p. 103) (because the individual must be able to hear what is being said above the background noise).


Importance of central (brain) auditory factors in hearing ability of older people, which factors are not reflected in the conventional audiogram.


Need to distinguish between self-perceived hearing disability and that which is determined by experimental testing procedures (although it could be argued that these were complex measurements of hearing impairment rather than measurements of hearing disability). For a given hearing threshold level, self-perceived hearing disability becomes less with increasing age; hearing disability determined by testing becomes greater with increasing age.


Factors comparable in magnitude to the ageing, gender, noise and socio-environmental ones that have yet to be included in the formulae to ‘predict’ hearing threshold levels; this particular study demonstrated significant associations of both measures of whole blood viscosity and derived measures of red blood cell rigidity with hearing threshold levels in individuals with sensorineural hearing impairments. The effect is clearly complex. At 4 kHz and 8 kHz, thresholds were related to red cell filterability; at lower frequencies, to whole blood viscosity.

122 A collaborative study of Glasgow University’s Department of Medicine and the Medical Research Council’s Institute of Hearing Research (Scottish section).

Demonstration from epidemiological data that disease of circulation affects the hearing.


What should be considered to be the limit of non-harmful noise for adolescents? Suggests a maximum of 70 dB SPL in the octave band centred on 500 Hz and 60 dB SPL on the band centred on 4 kHz. Although they were derided at the time as being much too low these values are consistent with the 71 dB(A) in ISVR’s 1994 formula.


The best mathematical expression to describe the relationship between the magnitude of a physical stimulus and that of the resulting sensory response. There is:

no challenge to the hypothesis that the power function constitutes a reasonable good first approximation of the underlying psychological law defining the relationship between stimulus intensity and psychological magnitude. (at p. 297)


There is no rule superior to the energy rule for dealing with impulse noise.


Financial incentives can enhance patient compliance with healthcare treatments.


(a) This work coined the term ‘socioacusis’. (b) An ear with inner ear disease already present is not more susceptible to noise damage (at p. 102).

What constitutes a hearing disability?

we had the subject say if he thought his hearing was good, fair or poor. In no case
did we encounter one who said his hearing was other than good if his hearing was
good up to 2 kHz. It did not matter much what happened above 2 kHz. Those who
had losses at 2 kHz, however, recorded fair and bad.

University Press, chapter 38.

Legal developments in respect of occupational noise-induced hearing loss
in New York State (at p. 866).

and disability. Paper read at Annual Meeting of the American Academy of Otolaryngology –

Criteria that should be met before a tinnitus complaint should be consid-
ered valid:

• The complaint (or claim) that tinnitus was present and disabling must
have been unsolicited. If the complaint was not present in the medical
records prior to the claim, it seems reasonable to assume that it arose
as a consequence of the interview and medical history process.
• The tinnitus must accompany a compensable level of hearing loss.
• The treatment history must include one or more attempts to alleviate
the perceived disturbance by medication, prosthetic management, or
psychiatric intervention.
• There must be evidence to support the idea of personality change or
sleep disorders.
• There must be no contributory history of substance abuse.
• The complaint of tinnitus must be supported by statements from family
or significant others.

These six criteria constitute the guidelines that are used by the Veterans
Administration (ex-servicemen’s organization) of the USA in the assess-
ment of claims for tinnitus.


Difficulty in distinguishing hearing loss due to ‘pure’ ageing and that influ-
enced by environmental factors; use of term ‘age effects’ would encompass
change in hearing threshold level with age that is attributable to physiological
ageing together with that due to unspecified environmental factors.

Recommendations for a detailed schema for describing otoscopic findings in epidemiological studies of otitis media (at pp. 275–7).


Deterioration in hearing threshold levels with increasing age: a logarithmic formula fitted to data.


Large-scale surveys indicating that left ears are, on the whole, one or two decibels poorer than right ears.


There is no mention of an acute form of occupational noise-induced hearing loss.


Need for otolaryngologists to acquire knowledge of medicolegal matters:

This is not a surgical text . . . but the foundation for the practical . . . The ‘Terminal care of head and cancer patients’ is dealt with in less than six pages, whereas 43 pages are devoted to ‘Legal and Ethical matters’. This is not a criticism . . . The difference in allocation could well reflect need; with the appearance of clinical thanatologists there may well be less need for surgeons in terminal care situations; both ethics and litigation are growth industries; they are relevant to terminal care also.


Relevance and standing of World Health Organization (WHO) documents, for example ‘A Manual of Classification Relating to the Consequences of Disease’:

WHO says that it has three main functions: to set normative standards; to provide technical advice and assistance on medical matters; and to advocate changes in health policy. During its 46 years history the first two functions have been a constant

123 Official publication of the Young Consultant Otolaryngologists Head and Neck Surgeons and the Association of Otolaryngologists in Training.
and uncontroversial backbone through which WHO has earned its reputation for scientific excellence.


Tinnitus associated with occupational noise-induced hearing loss: a review of literature, but no mention of tinnitus.


A scheme (categories) of grading degrees of hearing impairment. It was subsequently adopted by WHO for its ICIDH-1.


Age and hearing loss affect recognition of speech degraded by reverberation or time compression, but age effects are evident primarily in the most severe distortion conditions. Recognition of undistorted speech in noise affected by hearing loss but not by age. The findings are consistent with hypothesis that increased age produces a reduction in functional signal-to-noise ratio.


Age influencing speech recognition as the number of acoustic degradations of the speech signal increases.


Experimental demonstration that speech recognition by elderly listeners with a hearing loss is influenced by a combination of auditory processing factors, memory demands, and speech contextual information.


Hereditary hearing loss frequently goes undiagnosed: 'Hereditary hearing loss, especially if syndromal, is frequently undiagnosed despite all the recent information that has accumulated' (Preface).

**GOWERS E** (1973) The Complete Plain Words (revised by Sir Bruce Fraser). London: HMSO.
The use of word ‘guide-lines’. ‘The written language is as subject to the whims of fashion as is speech or dress or art . . . Here then is a list of words (includes ‘guide-lines’) that, at the present time, and in certain sorts of writing, can be classed as vogue words’ (pp. 204–6).


The foundation for the current systematic clinical examination of hearing. The scheme included whispered and conversational voice tests together with the Weber and Rinne tests and the use of tuning forks ranging from 64 Hz to 4096 Hz. The scheme was officially adopted at Eighth International Congress of Otology in Budapest in 1909.


Range of frequencies needed to hear speech: ‘For public telephone systems, the CCITT recommendation for the voice band is 0.3 to 3.4 kHz’ (at p. 12).


Causal relationships: ‘An association between two variables is likely to be causal if it is strong, consistent, specific, plausible, follows a logical time sequence, and shows a dose-response gradient’ (at p. 422).


‘Narratives offer a method for addressing existential qualities such as inner hurt, despair, hope, grief and moral pain which frequently accompany, and may even constitute, people’s illnesses.’


The preponderance of middle ear disease as a cause of hearing loss at that time:

Between December, 1921, and December, 1924, at the Royal Navy Hospital, Plymouth, 167 ratings were invalided from the service on account of deafness . . . Of these 167 ratings, 74 per cent. were suffering from suppurative middle-ear disease, 17 per cent. from chronic middle-ear catarrh, and only 3 per cent. from diseases of the ear directly attributable to the service — namely, traumatic rupture of the tympanic membrane and labyrinthine deafness.
Evidence that in the second half of the nineteenth century not only were there people complaining to doctors of most disturbing tinnitus but that the doctors were unable to manage these patients and desperately needed some effective treatment. In the search for a cure Joseph Toynbee died on 7 July 1866 from experimental inhalation of cyanic acid and chloroform vapours.

Longstanding basis of both pathology (at p. 281) and psychology (at p. 273) as foundations of clinical knowledge. The former was established by Carl Rokitansky (1804–78) who was Professor of Pathology in Vienna and the latter was incorporated by Johannes Müller into his Handbuch der Physiologie des Menschen (1833–40).

Deriving a scale of ‘auditory handicap’. Based upon asking patients at both a Cairo hospital and a London hospital ‘Assuming that there is a scale of hearing handicap from zero to a hundred (where a hundred is the handicap produced by complete deafness), how much of a handicap on this scale would you say that your hearing difficulty gives you?’ But these studies were conducted two years before WHO defined ‘handicap’ essentially as the non-auditory consequences of a hearing impairment. Thus according to such a definition the term ‘auditory handicap’ is meaningless. So what dimension were the patients scaling? In retrospect (as the title says), the ‘subjective magnitude of auditory impairment’; certainly it was neither hearing disability nor the handicap resulting from such a disability.

Continued use by the Medical Research Council of the frequencies 0.5, 1, 2 and 4 kHz to provide an index of hearing ability (‘the four frequency average’ or ‘FFA’) (at p. 1027).

A case (Case 1) of auricular malformations associated with hearing loss in a 14-year-old boy with a family history of the condition, complicated by acoustic trauma (due to toy pistol) on one side and chronic middle ear
infection on the other side. ‘Accordingly his hearing was low on both sides, audiometric tests showing a hearing loss of the mechanical type on the right side, and a combined one on the left side’ (at p. 214) (unfortunately no audiograms were included in the publication).


Reduced red blood cell deformability in cases of sudden sensorineural hearing loss (Scottish workers have suggested that reduced red blood cell deformability may partly explain the increased blood viscosity associated with high blood pressure).


Appropriateness of the various audiometric matching tests for tinnitus. Only audiometric matches of the tinnitus ‘intensity’ in terms of personal loudness units (PLUs) were significantly correlated with reported loudness or other psychological scales; unlike the other measures of tinnitus ‘intensity’, PLU transformations of tinnitus ‘intensity’ produced tinnitus ‘intensity’ values that were generally independent of other audiometric measures.


Psychological facets of tinnitus: (a) both psychosomatic and somatopsychic factors are to be found; (b) distressing tinnitus is not related to auditory features of the tinnitus nor to neuroticism; relationship to life stresses, including redundancy.


Endolymphatic hydrops starting as a sudden hearing loss.


Normal cochlear structures in 75-year-old man with severe sensorineural hearing loss.


Histopathological evidence that endolymphatic hydrops may be associated with a *sloping high frequency* hearing loss.

Confirming that subjective magnitude estimates of area cannot be equated with objective magnitude measurements of area (using artificially made temporal bone eardrum perforations). The relationship is unaffected by clinical experience. It is necessary to bear in mind this particular example of the psychophysical phenomenon when comparing eardrum photographs with sketches in clinical notes.


Influence of direction of sweep: relationship of continuous and pulsed audiograms to one another is essentially the same whether obtained in an ascending or descending mode unless abnormal auditory adaptation is present.


Speech recognition difficulties experienced in noise by elderly listeners do not result solely from reduced auditory sensitivity.


Dangers of extrapolation.

A common technique in statistics is to plot a series of points on a graph and then draw a line of best fit across the graph . . . The line of best fit is used to predict values, and it is in this context that interpolation and extrapolation arise. **Interpolation** consists in reading a value on that part of the line which lies between the two extreme points plotted . . . **Extrapolation** means reading a value on the part of the line that lies outside the two extreme points plotted . . . The distinction between the two is necessary, for although interpolation is permissible, it is considered dangerous to extrapolate. In the case of interpolation, the actual points on the graph give a sound indication of the possible error that could arise in reading a value from the line. But, where the line lies outside the plotted points, there is no guide at all to the degree of error. Although the plotted points may suggest that the line has a steady slope, it may well be that some new, unsuspected factor comes into play at the higher or lower levels which, unknown to us, alters the slope in those regions. (at pp. 223–4)

If the curve that has been fitted to the data is not a straight line, the exercise of extrapolating is doubly dangerous.

Effect of procedure on measured auditory threshold: computer-controlled simulation of different procedures showed two different ‘manual audiology’ simulated procedures gave thresholds differing by 3.5 dB, the more sensitive manual procedure being 1.5 dB less sensitive than the ‘self-recording’ procedure.


Experimental demonstration of the value of hearing aids for patients with noise damage to the ear.


(a) A convenient, succinct account of physics relevant to the measurement of auditory function. (b) Providing an illustration of how even the British Standard for the audiometric reference zero has been changing. Depending on the frequency, the 1972 reference zero showed changes of up to 2.5 dB when compared with the 1954 standard (at p. 111).


(a) An addition to the repertoire of tests available to examiners to detect NOHL. (b) Normally hearing volunteers are able to simulate a ‘partial deafness’ of about 44 dB, which levels ‘were surprisingly consistent from test to test’ (at p. 135).


How the clinician goes about diagnosis: a pattern recognition exercise. The book contains more than 50 colour photographs to show varying appearances (reflecting different disease processes) on looking at the outer ear, and more than 100 colour photographs to show varying appearances (reflecting different disease processes) on examining the ear with an otoscope. There are no formulae or equations.

How the clinician goes about diagnosis: a pattern recognition exercise. The book contains more than 30 colour photographs to show varying appearances (reflecting different disease processes) on looking at the outer ear, and about 100 colour photographs to show varying appearances (reflecting different disease processes) on examining the ear with an otoscope. There are no formulae or equations.


Debates on a ‘low fence’ for any hazardous physical, chemical or biological agent. Reference to studies of US Navy Shipyard workers (as well as people in Brazil, China and India) who had been exposed to low level radiation but had suffered from fewer cancers than non-exposed workers.


Susceptibility to disease, including occupational noise-induced hearing loss, being genetically determined and therefore, at the basic level, being a dichotomous phenomenon, rather than a question of degree. In other words there really are ‘tough’ ears that do not show evidence of noise damage. The continuous frequency distributions produced by statistical analyses are thus, in actuality, quasi-continuous distributions:

Scientists in Scotland have shown that a smoker’s fate may depend on a single gene, which provides a defence against the toxic chemicals in tobacco smoke . . . Professor Roland Wolf, who led the team from Dundee, Glasgow and Edinburgh said yesterday: ‘. . . The gene is the one responsible for making an enzyme called glutathione S-transferase that appears to have a protective role’. (at p. 1)

HAWKES N (1999) Big Bang mystery put to £186m test. The Times (10 May), p. 11.

Impossibility of even the most precise of the sciences, physics, of predicting outcomes. ‘In theory the Big Bang ought to have produced exactly equal numbers of particles and antiparticles, which annihilate each other when they meet. Had it done so, the universe ought to have disappeared before it had begun. Plainly, that did not happen.’


The impossibility of predicting the hearing threshold levels for individuals:

It seems that there are well-defined laws that govern how the universe and everything in it develop in time . . . The human brain, however, is also subject to the uncertainty principle. Thus there is an element of randomness associated with quantum
mechanics in human behaviour. But the energies involved in the brain are low, so quantum-mechanical uncertainty is only a small effect. The real reason why we cannot predict human behaviour is that it is just too difficult... The human brain contains about $10^{26}$ or a hundred billion billion particles. This is far too many for us ever to be able to solve the equations and predict how the brain would behave, given its initial state and the nerve data coming into it... So although we know the fundamental equations that govern the brain, we are quite unable to use them to predict human behaviour... This situation arises in science whenever we deal with the macroscopic system, because the number of particles is always too large for there to be any chance of solving the fundamental equations. What we do instead is use effective theories. These are approximations in which the very large number of particles is replaced by a few quantities. An example is fluid mechanics. A liquid such as water is made up of billions of billions of molecules... The predictions of the effective theory of fluid mechanics are not exact – one only has to listen to the weather forecast to realize that – but they are good enough for the design of ships or oil pipelines. (pp. 115–22)


Need for hesitancy on part of examiners before diagnosing (labelling) an individual as having one or other medical disorder. Such an action, whether right or wrong, results in adverse medical and psychological effects. Guidelines to avoid labelling in respect of noise damage to hearing would be for the examiner not to make such a diagnosis unless the audiogram shows either bilateral symmetrical notching at or around 4 kHz or a bilateral symmetrical abrupt down slope of the audiogram and the degree of inferred noise-induced permanent threshold shift is greater than an inferred age-associated permanent threshold shift that would merit a diagnosis of presbyacusis.


(a) Sound hypersensitivity may be associated with hypersensitivity to other sensory stimuli, such as light and touch. (b) Hyperacusis in tinnitus patients responds well to treatment: low-level wide-band noise to the affected ear for six hours per day for several months.


(a) What constitutes a significant hearing loss: a hearing threshold level (averaged over the frequencies 1, 2 and 3 kHz) of 30 dB or more, that is, as
defined by BS 5330: 1976 (at p 2). (b) In a typical industrial population, and by the age of 55 years, the proportion of workers who are likely to have such a hearing loss are as follows: 69% who have been exposed to an equivalent continuous sound level of 100 dB(A), 16% who have been exposed to 95 dB(A), 30% who have been exposed to 90 dB(A), 16% who have been exposed to 85 dB(A), and 12% who have had no hazardous occupational noise exposure (at p. 3). (c) Auditory symptoms other than impairment of hearing that result from noise damage to hearing:124

Tinnitus (‘ringing in the ears’) can become permanent. Many people find this as distressing as the hearing loss.125
Diplacusis (double hearing) in which a sound will have a different tone in each ear, or will sound rough. This will contribute to lowered intelligibility of speech, which cannot be improved by a hearing aid.126
Loudness recruitment is a common feature of noise-induced hearing loss. This involves a distortion of the response to sounds of different loudness. It is greatest at low levels, and affected people often find it more difficult to communicate in a quiet environment than a noisy one.127

These effects are not yet enough understood for a reliable dose/effect relationship to be produced.128 They are, however, thought likely to be caused by noise exposure at the levels likely to cause hearing loss, so any action to reduce this loss will help reduce their occurrence. (at p. 3)


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124 The clinical source of this section is not stated.
125 This picture is not that which has emerged from direct examinations over the years of workers in Britain exposed to hazardous occupational noise levels (for example, Barr, 1886; McKelvie, 1937; Johnston, 1953; Atherley and Noble, 1971); tinnitus occurs early, if at all, in the course of hazardous occupational noise exposure and is not a prominent feature of such exposure.
126 Nevertheless it is clear that people in both Canada (Alberti, 1986) and the UK (Harrowven, Greener and Stephens, 1987) with noise-damaged hearing can obtain substantial benefit from hearing aids.
127 There seems to be a confusion here between loudness recruitment and other paracuses.
128 The inability to establish a gradient (a criterion required by medical epidemiologists, for example Hill and Hill, 1991, which appears to be endorsed by lawyers – for example, Machin, 1990) seriously questions the role of hazardous occupational noise exposure in the causation of these hearing effects.
129 This included Professors W Burns and DW Robinson.
Limiting sound levels:

**Foreword** By the Right Hon. Robert Carr, MP, Secretary of State for Employment: It has been common knowledge for many years that high levels of noise can cause impairment of hearing . . . The general solution to this problem, which is a complex one, has been hampered more by ignorance than by neglect. Until the pioneer work of Professor Burns and Dr Robinson was published in March 1970, we lacked the necessary scientific knowledge of the precise levels of noise, and the duration of exposure to them, which can cause damage. It is largely due to their work that this Code of Practice has been made possible. . . .

Section 1: 
**Scope of Code**
1.1.2 The Code sets out recommended limits to noise exposure. It should be noted that, on account of the large inherent variations of susceptibility between individuals, these limitations are not in themselves guaranteed to remove all risks of noise-induced hearing loss. . . .

Section 4: 
**Limits**
4.1 Desirable sound levels.
4.1.1 The limits set out in this section should be regarded as maximum acceptable levels and not as desirable levels. Where it is reasonably practicable to do so it is desirable for the sound to be reduced to lower levels.
4.2 Limiting sound level
4.2.1 People should not be exposed to sound levels exceeding the limit set out in 4.3 to 4.5 below . . .
4.3 Continuous exposure
4.3.1 If exposure is continued for 8 hours in any one day, and is to a reasonably steady sound, the sound level should not exceed 90 dB(A)
4.4 Non-continuous exposure
4.4.1 If exposure is for a period other than 8 hours, or if the sound level is fluctuating, an equivalent continuous sound level \( L_{eq} \) may be calculated and this value should not exceed 90 dB(A) . . .


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130 A reprinting, without amendments, of the Code, which was first published in 1972 under the auspices of the Department of Employment.
Following an EEC directive of 12 May 1986, the Noise at Work Regulations 1989 made under the Health and Safety at Work Act 1974 came into force on 1 January 1990. The regulations apply to all workers in Great Britain covered by the Health and Safety at Work Act except the crews of seagoing ships and aircraft. The Health and Safety Executive published Noise at Work: The Noise at Work Regulations 1989 to provide guidance to employers (Noise Guide No 1) and to designers, manufacturers, importers, and suppliers (Noise Guide No 2) regarding their legal obligations to prevent damage to hearing. Regulation 7 effectively codifies the employer’s common-law duty to reduce, so far as is reasonably practicable, the exposure of employees to noise. It is not expected that an employer should incur such costs as to make his business uncompetitive but if the sound levels in which an employee is working cannot be brought down to acceptable levels then personal hearing protection (HPDs) must be worn. This is a common law duty that has been codified in regulation 8. The actual action to be taken depends on the measured noise exposure. The latter is given in terms of either the daily personal noise exposure ($L_{EP,d}$) or the peak sound pressure of the noise. Regulation 2 defines three action levels:

First action level: $L_{EP,d}$ of 85 dB(A)
Second action level: $L_{EP,d}$ of 90 dB(A)
Peek action level: peak sound pressure 200 Pa (140 dB SPL)

Where employees are exposed between the first and second action levels, regulation 8(1) requires employers to provide protectors to employees who ask for them. Where employees are exposed above the second or peak action levels, regulation 8(2) requires employers to provide protectors to all employees, and regulation 10 requires both the employers and the employees to ensure that they are worn. The Noise Guides now replace the 1972 Code of Practice.


Generalized linear interactive modelling, the statistical technique used by the Medical Research Council to analyse the data from the National Study of Hearing.


We all find that we have tinnitus if the surroundings are sufficiently quiet. Moreover, the features of such tinnitus are indistinguishable from the tinnitus of the patients seeking medical advice.
Experimental demonstration that tinnitus can be induced consistently (51 out of 57 subjects) by deliberate stimulation of the ears with high-level (110 dB SPL) noise, but is of limited duration (‘in most cases it disappeared within a few minutes of removal of the stimulus . . . For a small minority of subjects it lasted a few hours and on two occasions into the following day’ (at p. 210).

Interchangeability of the intensity of a noise and its duration when considering the damaging effect of noise:


Existence of a ‘toughening process’ from experiments showing clearly that the hearing system can become resistant to repeated daily noise exposures. These studies therefore cast doubt on claims that a sudden hearing loss attributable to hazardous occupational noise exposure can occur months or years after such exposure started (at pp. 476–88).


Growth of asymptotic threshold shift consequent on exposure to repeated impact noise much more rapid than that developing after exposure to continuous noise.


Experimental demonstration that, above a critical level, the effect of noise on the cochlea shifts from metabolic to direct mechanical damage with disruption of cochlear architecture.

Magnitude of hearing loss produced by impact noise being more dependent on the peak sound level of the impulse than on the total energy level of the noise exposure. Experimental exposure of animals to impact noise where duration, repetition rates, and peak level were adjusted to ensure each experimental exposure had the same total sound energy, but marked noise-induced permanent threshold shift (NIPTS) was produced by peak levels above 125 dB SPL. This was associated with substantially greater loss of hair cells.


(a) Constraints imposed for ‘administrative convenience’: by (i) limiting types of jobs to which scheme applied, (ii) requiring 20 years of employment, (iii) requiring claimant to make the claim within one year of finishing the job – not by introducing a high ‘low fence’. (b) The course of the occupational noise-induced hearing loss: over 30% (of 586 cases) improved and less than 25% deteriorated (by 10 dB or more) over a five-year period; so if there has been a change in the claimant’s hearing it is more likely that it has improved, and by at least 10 dB, with the passage of time.


Noise levels when welding: range from 65 dB(A) to 74 dB(A) for TIG (tungsten inert gas) welding to 98 dB(A) to levels in excess of 110 dB(A) for plasma cutting welding.


Socio-economic factors in general: primarily genetic.


Misinterpretations of findings of the Industrial Diseases Subcommittee of the Industrial Injuries Advisory Council (DHSS, 1973): ‘The union\textsuperscript{131} estimates that the lives of half a million workers have been ruined by industrial deafness . . .’

\textsuperscript{131} General, Municipal, and Boilermakers’ Union
A tendency to deny or minimize problems associated with occupational noise-induced hearing loss; but this tendency also noted with other types of hearing loss.

(a) The complexity of the effects that may be associated with occupational noise-induced hearing loss; but this applies also to effects associated with other types of hearing loss; study based upon a ‘group of 61 workers\textsuperscript{132} from a metal product plant\textsuperscript{133} . . . 66% had abnormal hearing according to their age. Interviews on hearing problems and on their consequences were conducted at home with the spouses’ (Abstract).

(b) The role of relatives:

the present study leads us to conclude that any valid assessment of the handicap due to occupational hearing loss must take into account the involvement of the near relatives (especially the spouse) of the hearing-impaired person. (at p. 261)

\textsuperscript{132} Derived from an initial group of 100 workers.

\textsuperscript{133} In Québec.
‘26% of adults report great difficulty with speech in noise.’) (d) Tendency of factory workers not to complain about noisy conditions:

When we commenced our survey, we were intrigued by the repeated statement at professional meetings and in scientific papers that employees in noisy workshops seldom complained to management about noise, or went on strike on this account, as sometimes happens with uncomfortable thermal conditions. (at p. 131)

(e) Absence of evidence relating headaches to hazardous occupational noise exposure.


Emotional reactions from scientists do not characterize the response to publication of new data, concepts, or formulae; even the greatest paper by the twentieth century’s greatest scientist was met with ‘an icy silence’; two years after publication of the paper, Max Planck wrote to Einstein to say that supporters of relativity were only ‘a modest sized crowd’.


(a) ‘The essence of an experiment . . . lies in comparison. To the dictum of Helmholtz that “all science is measurement” we should add, as that great experimenter Sir Henry Dale pointed out, a further clause, that “all true measurement is essentially comparative” (at p. 5). (b) A cause–effect relationship: before arguing for such a relationship it is necessary to establish, inter alia, (i) consistency of the observed association: ‘Has it been repeatably observed by different people, in different places, different circumstances and time?’ (at p. 273); (ii) a biological gradient (dose-response curve) of an association between two measures before arguing for a cause–effect relationship: ‘For instance, the fact that the death rate from cancer of the lung has been shown to rise linearly with the number of cigarettes smoked daily adds a very great deal to the simpler evidence that cigarette smokers have a higher death rate than non-smokers’ (at p. 275); because of the non-specificity of both the clinical and the audiometric picture of occupational noise-induced hearing loss, establishing such a relationship is particularly important for jobs where a noise risk to hearing

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134 Suggestions of a ‘deafening silence’ with which the publication of an MRC paper was received.

135 Einstein A (1905) Zur Elektrodynamik bewegter Körpen (On the electrodynamics of moving bodies). Annalen der Physik und Chemie 17: 891–921. This was the paper that introduced his theory of relativity.
is alleged. The difficulty is compounded by the need to exclude the effect of ageing on hearing – an effect that is more pervasive than the effect of occupational noise. (c) The standing of Bayesian methods:

Many statisticians feel that the whole concept is too vague, and that it should be possible to derive the meaning of data without resort to prior probabilities. They say that if the results are to depend upon such a concept, then they do not trust those results, whereas if results do not depend on it, why introduce it? The opposing school reply that nobody in his senses would try to interpret results without taking previous information into account and it is better to do things formally than informally. Furthermore, by trying different sets of prior probabilities on the same data, if the results are widely different it shows that the data are not themselves supplying a firm answer, whereas if the results are much the same each time, then those results are trustworthy. (at p. 173)


Secular changes in noise intolerance. Data on noise complaints and on upheld noise nuisances for a sample period (1967/72) collated and graphically presented. Conspicuous increases over that period (at p. 106).


The importance of the single case report with clinical-pathological correlations and its contribution to expanding medical knowledge (integrated into the corpus of clinical science with 62 references). Investigations of blood chemistry revealed changes that had not hitherto been reported.


Experimental demonstration that one could induce tinnitus by the deliberate application of noise (up to 120 dB SPL for one minute) to an ear, but this was short lived. The tinnitus ‘invariably followed stimulation with the more intense noise bands, although subjects spontaneously reported bilateral, but consecutive, tinnitus. Characteristically . . . disappearing about 2 mins. after cessation of the stimulus’ (at p. 507). The appearance of tinnitus in the non-stimulated ear has been attributed to the operation of the efferent nervous system.


(a) Date when British management ought to have known about the hazards of occupational noise exposure: the paper (given at a conference organized by, and published in the journal of, the British Occupational
Hygiene Society) was addressed, inter alia, to ‘managerial staff’; but the question remains as to how many such people either attended the conference or read the journal. The industrial medical officers of the larger companies would, however, have been present. (b) Distinguishing between potential and proven damaging effects: ‘A noise analysis alone will only indicate the potential hazard. The actual hazard must be directly measured. Permanent noise-induced hearing losses may be discovered by single-frequency\(^{136}\) screening audiometry, but the degree and course of these defects can only be determined by serial full-frequency threshold determinations’ (at p. 65).


(a) Hearing threshold level at 4 kHz in men related to use of military rifles. (b) Problems/uncertainties regarding ‘normal’ hearing threshold level at 6 kHz and calibrations at this frequency.


(a) Quantitative data for looking at changes\(^{137}\) in hearing threshold levels with increasing age. (b) A gender difference in hearing threshold levels that was the pattern of noise damage (maximum at 4 kHz, with male thresholds poorer than female thresholds), but no significant hazardous occupational noise exposure for subjects; noise source was primarily acoustic trauma arising from military service or using guns for hunting. (c) If female thresholds were taken as the applicable non-noise exposed thresholds, no evidence for the convergence that characterizes civilian occupational noise-induced hearing loss, but if male ISO 7029 thresholds are taken as the applicable non-noise exposed thresholds then convergence is seen.


Formulae to express changes in hearing threshold levels with age: first in a series from a number of institutions, which formulae would come to include gender, socio-economic grouping, noise exposure level and duration, but neither this author nor anyone else at the time suggested that such formulae could or should be used for diagnosis in respect of individual patients.

\(^{136}\) 4 kHz.

\(^{137}\) There has been a persisting misinterpretation of the published tables and graphs since then.

(a) 21–39% of general population (depending on age) have experienced tinnitus at one time or another. (b) Failure to demonstrate a link between having experienced tinnitus and having a history of potentially hazardous occupational noise exposure. (c) Hearing threshold level (HTL) at 2 kHz in rural population correlated with use of 12-gauge (bore) shotguns; specifically

\[
H_2 = 3.93 \log N + 1.5 \text{ dB}
\]

where \( H_2 \) = hearing threshold level at 2 kHz
and \( N \) = stated number of rounds fired.


Differences from one specialist to another in the interpretation of X-ray films of what might be considered even simple anatomical structures.


Source of errors in epidemiological studies of hearing, including those where effects of noise are being studied.


Various ear conditions that can result from exposure to hazardous noise levels: a chronic disorder (occupational noise-induced hearing loss), and several acute conditions (acoustic trauma, acoustic accident, and otic blast injury).


By inclusion of a section on the pathology of injuries to the ear (including noise damage) recognition by pathologists that ear pathology was an integral part of pathology.


\(^{138}\) Set up in October 1967 to review the state of knowledge of pathology in the field of trauma.
A mathematical function: defined as the expression using mathematical symbols of the relationship between two or more variables (a quantity that does not take a fixed value); examples given include a power function (at p. 7), which describes the psychophysical law, and a Gompertz function (at p. 8), which describes biological growth.


(a) Drawing attention to otolaryngologists of the scientific basis of designing experiments. (b) Mathematical form of speech audiogram in sensorineural hearing loss:

Thus a third-degree polynomial fitted to the speech audiogram of Fig. 18 has the form

\[ y = 120 - 7.7x + 0.135x^2 - 6.464 \times 10^{-4}x^3 \]  
(2.69)

where \( y \) = percent words correctly repeated

and \( x \) = speech material sound level in dB (relative scale).


Drawing the attention of otolaryngologists to the epidemiological basis of the specialty.


An analysis of the relationship between assessed percentage disability and compensation awarded in common law cases. Conformity with Stevens’s power function but there has been an increase with chronological time in excess of what could be accounted for by inflation; specifically

\[ P = k.e^{ct}.D^n \]

where \( P \) = award in pounds sterling

\( D \) = assessed percentage disability

\( c \) = a constant (0.214)

\( k \) = a constant (5.17*10^5)

\( n \) = exponent (0.67)

\( t \) = year of the twentieth century.


(a) Distinguishing between the various auditory symptoms (the hypoacuses, dysacuses, dysstereoacusis, tinnitus, auditory hallucinations) (at p. 1). (b) Pattern of speech audiogram in abnormally hearing ears:
Abnormally hearing ears may show one or more of four changes in the curve, i.e.
(1) a shift of the curve to the right (speech hearing loss);
(2) a failure to achieve a score of 100% or thereabouts (discrimination loss);
(3) a reversal of the direction of the curve (rollover); and
(4) a decreasing slope of the rising segment of the curve.

No mention of an increasing (steeper) slope (at p. 11).


The variety of abnormal auditory sensory phenomena (paracuscs) that may be detected in individuals. It includes both intensity coding abnormalities, such as loudness recruitment, and frequency coding abnormalities, for example sound distortions such as hearing two tones instead of one, or no tonality at all; it may be possible to demonstrate one or more of these phenomena in a variety of hearing diseases; none of the phenomena are specific to noise damage to hearing; the majority of patients are unaware of the presence of these paracuscs (at pp. 346–51).


Distinguishing between the various types of sensitive (hyperacusis, oxyae- coia, phonophobia) or distorted hearing (at pp. 221–5).


Scope of, and methods for, the much neglected clinical examination of ear function (hearing and balance).


The ‘low fence’. The King–Kopetzky syndrome unifies ‘auditory disability with normal hearing’, auditory dysacusis, auditory inferiority complex, loss of the capacity for discriminative listening, obscure auditory dysfunction and selective dysacusis into a single condition for which occupational noise-induced hearing loss is not a cause.


(a) The ageing component in the MRC age/noise formula is consistent with the ageing component in the ISO 7029. (b) Non-specificity of audiometric patterns.


No mention of ‘acoustic accident’ because the editors considered that ‘acoustic accident’ had not been proven to exist as a distinct entity.


Complexity of socio-economic factors influencing measured hearing threshold level.


(a) Need to distinguish between reference zeros for the calibration of audiometers and population norms for hearing threshold levels (at p. 365). (b) The numerical models of hearing used in medicolegal reports are statistical, and not mathematical, models – they are not formulae to set precise values to a plaintiff’s hearing threshold levels (at p. 368).


(a) A number of factors, including those related to age, gender and socio-economic level, influence the level of the threshold of hearing even in cases where no relevant medical disorder can be detected. (b) A number of age/noise statistical formulae, each with specific indications, are available to medical examiners as ancillaries to diagnosis. Two different models may show substantial agreement. The limitations of models. (c) The ‘low fence’:

It has been argued on theoretical grounds that ‘every decibel counts’. Nevertheless clinicians involved in hearing disorders do not expect people to complain about their hearing unless average hearing threshold levels are in excess of about 20 dB, or rather, if they do, then the cause is not occupational noise-induced hearing loss.


140 Invited contribution.
ISO 389 being a standard to which audiometers must adhere. It is not a standard to which the hearing of individuals must adhere. There is no reason why a calibration standard for any instrument should conform to a biostatistical measure. A continually changing standard militates against detecting and measuring secular changes in hearing.


Bases for intra- and inter-examiner variability.


A ‘low fence’:

WHO has defined what it terms a ‘disabling hearing impairment’. For adults this is defined as a permanent unaided hearing threshold level of 41 dB or greater. It will be noted that a quarter of a century ago, the British Association of Otolaryngologists suggested that the level of hearing loss appropriate to the requirements of the Industrial Injuries Act would be an average of 40 dB or more over the 1,000, 2,000 and 3,000 Hz frequencies (Department of Health and Social Security). Plus ça change, plus c’est la même chose. (at p. 700)


Ways of assessing changes in the quality of life consequent on hazardous occupational noise exposure. A number of formulae that relate ‘disability’ and/or ‘handicap’ to measured hearing threshold levels, but they need to be reconsidered in view of positive aspects of hearing impairments and to be re-evaluated as a result of the World Health Organization replacing its 1980 Classification with the International Classification of Impairments, Activities, and Participation: A Manual of Dimensions of Disablement and Functioning.


Medical examiners are unable to demonstrate that exposure to an equivalent sound level of 96 dB(A) for 1.5 to 5 years can affect the hearing. Moreover, they are unaware of that inability.

The need, by observing International Noise Awareness Day on 21 April 1999, to draw the attention of the various authorities to the effect of noise on our quality of life and what can be done about it.


The nature and value of Békésy audiometry in the investigation and measurement of disorders of hearing, including that resulting from occupational noise damage (a review).


‘Low fence’. Extension of ‘every decibel counts’ concept to ‘every attobel counts’, but such values can neither be detected nor measured. The importance of the principle for public health medicine.


(a) How to determine the \textit{individual} loudness function for an individual claimant. (b) Most comfortable loudness level for tinnitus patients is, on average, 17 dB lower than that for normals.


(a) Acknowledges Barr’s study as ‘The first systematic study of occupational noise-induced hearing loss in Great Britain’. (b) Dizziness, and therefore any disorder or syndrome characterized by dizziness, is not attributable to hazardous occupational noise exposure.


The relative influence of various aural symptoms on subjective magnitude of loss of ability to enjoy life. The latter could be predicted from subjective magnitude of three symptoms (dizziness, sound distortion and impaired hearing). The subjective magnitudes of tinnitus and disturbed sound localization were not significant factors. There was no suggestion that tinnitus was considered to be a distressful condition. The sample of

\textsuperscript{141} Prepared for the occasion of the International Békésy Conference on Hearing and Related Sciences, Budapest, June 1999.
patients studied was not restricted to those with a sensorineural hearing loss, let alone those with noise damage to the hearing.


Data on threshold levels of a random sampled adult Jamaican population.


Tinnitus, inter alia, in occupational noise-induced hearing loss cases: ‘a symptom which characteristically is not distressing and which disappears with the passage of time’ (at p. 67).


There is a plethora of factors affecting threshold of hearing measured by manual audiometry (apart from factor in which one is interested).


No mention of the existence of an *acute* form of occupational noise-induced hearing loss.


Different results from different methods of testing: ‘we must conclude that hearing is whatever a particular hearing test measures, just as intelligence is defined as that which the intelligence test measures. This may sound more circular than satisfying, but it is consistent with an empirical, operational approach.’


Complexity of effects of noise on hearing: experimental studies show that under certain conditions the hearing does not recover gradually after a temporary ‘deafening’ effect but bounces (Bronstein’s bounce) up and down before settling down to a steady recovery pattern.


A ‘low fence’. Experimental study of combined hearing disability in quiet and in noise using a self-assessment questionnaire results in a threshold of
24 dB HTL. It is difficult to see how this fence of 24 dB HTL was ‘erected as an administrative convenience’.


Logic and the law. Holmes’s famous aphorism: ‘the life of the law has not been logic; it has been experience’ (at p. 1).


Tinnitus associated with occupational noise-induced hearing loss: the author (an otologist) had done a field study of 40 boiler-makers in Portland, Maine, USA. Neither he nor any of the five discussants at the meeting where the paper was presented mentioned tinnitus either in connection with boiler-makers specifically or in connection with occupational noise-induced hearing loss in general.


Distinguishing between the terms ‘average’ and ‘normal’ as used by clinicians. ‘Normal’ is a descriptive term that can be applied to any child who shows typical characteristics for his age. The term ‘average’ is derived from statistics (at p. 6). The comments also apply to adults.


Variable paradoxical effects of hearing impairment on musical appreciation: ‘What constitutes musical appreciation is so difficult to define’ (at p. 340):

The onset of deafness . . . is a tragedy to the instrumentalist . . . instrumentalists playing stringed and other instruments . . . have to rely critically upon their own hearing acuity . . . Pianists, organists and harpists . . . do not . . . have this problem, because, provided they strike the correct note the pitch is determined by the instrument. A professional organist of the author’s acquaintance continues to give a credible performance despite the fact that he has an appreciable high tone hearing loss . . . The effect of partial deafness upon conductors and composers is much less obvious, particularly in respect of presbyacusis . . . Vaughan Williams, whose deafness did not become obvious until his seventies, continued conducting until his 85th year culminating in a performance of the Bach *St Matthew Passion*. His deafness was sufficiently severe to warrant the use of a hearing aid. He found an electronic aid of little assistance, however, and much preferred a form of ear trumpet which he referred to as ‘his coffee pot’ . . . his widow . . . writes (personal communication) ‘I think it is difficult to estimate exactly how much deafness affected Ralph musically because he had a life-long knowledge of various works, of
the scope of instruments, and of experience of both writing and conducting music. Looking back, I’d say that knowledge and expectation of what should be there filled gaps in music and imagination. . . . Perhaps of even more serious consequences . . . from the point of view of musical appreciation, is the marked degeneration that occurs with age in our ability to discriminate tones of neighbouring frequency . . . Senile deafness, of course, has such an insidious progression (in common with other impairments of hearing) that few of us notice its advance with time. We adapt to our changing pattern so much so that many of the elderly stoutly deny that they have any problem . . . What they hear of a musical performance, therefore must differ, perhaps appreciably, from what is heard by say the younger members of the audience. Does their interpretation change with their sensory degeneration? . . . Are they perhaps through many years of experience so accomplished at their profession that good hearing is of less importance than a memory acquired over the years of what is called for during this or that passage of music? Do in fact the elderly with failing hearing derive any less enjoyment from a musical performance than the young? . . . No chapter on deafness as applied to music would be complete without some comment upon the deaf composers . . . Smetana . . . did not become deaf until he was in his late forties and by the time he had reached the age of fifty his deafness was total. He was much troubled with tinnitus and gave expression to this in the finale of his autobiographical *Aus mein Leben* quartet by means of a high sustained violin note . . . A common feature of all these composers is that the deafness progressed fairly rapidly and on this account it was without exception regarded by each of them as a very considerable personal tragedy . . . Tragedy of course it undoubtedly was to all these composers but the truly remarkable fact is that far from having an adverse effect upon their work, their deafness marked the period of their greatest creativity. Smetana for example, some years after he became deaf, wrote ‘I have completed in these three years of deafness more than I had otherwise done in ten’ . . . How much, one wonders, would have been lost to our musical heritage had these composers not been deaf?


Melanin factor in noise-induced hearing loss: the less melanin, the more noise-induced temporary threshold shift.


(a) Summary of distinctive features and advantages of Békésy audiometry: ‘the Békésy instrument placed the variables of test tone intensity and test tone duration under the control of the subject. Not only did the new instrument permit the subject to track his threshold . . . but also permitted measurement of the absolute threshold all along the frequency range instead of at octave and midoctave points’ (at p. 216). (b) Nature of a plaintiff’s hearing loss inferred from the pattern of his Békésy audiogram (at p. 235).

Even experts may be as overconfident as lay people once they are forced to go beyond their data and rely on judgement.


Greater hearing loss in workers who developed HAVS.


Tinnitus associated with noise exposure:

The tinnitus due to noise exposure is typically high pitched in nature, and is often described as whistling, ringing, or like escaping steam or air. It can usually be roughly matched to one of the test tones of the audiometer in the 2 kHz to 8 kHz frequency range. Low pitched tinnitus, especially of the pulsating kind, almost certainly accompanies disease of the ear or vestibular system . . . The incidence of serious disturbance among workers employed in heavy industry seems rather less than in the population as a whole. This perhaps results from some degree of self-selection in the first instance. (at p. 167)


(a) Normality and a ‘low fence’. The International Association of Physicians in Audiology considers a hearing impairment to be present if the better ear hearing threshold level (averaged over the frequencies 0.5, 1, 2 and 4 kHz) exceeds 20 dB.142 ‘In other words, the hearing is considered to be “normal” if the better hearing ear has an average < 20 dB HTL.’143 Although the criteria were primarily for assessing the hearing impairment/disability of children they can also be applicable to adults. (b) Information on hearing levels at which hearing aids are ‘advantageous’, desirable’, or ‘essential’.

142 Following the unanimous recommendations of a working group composed of Alberti (Canada), Bellman (UK), Hinchcliffe (UK), Parving (Denmark) and Prasansuk (Thailand).

143 It is difficult to see how this fence was ‘erected as an administrative convenience’.

The International Standard for the determination of occupational noise exposure and estimation of noise-induced hearing impairment. Note (a) interdiction against using statistical data to assess the hearing of individuals: ‘This International Standard is based on statistical data and therefore shall not be used to predict or assess the hearing impairment or hearing handicap of individual persons’ (at p. 1). (b) Defines an ‘otologically normal population’ as a ‘highly screened population’ (at p. 1). (c) Does not use noise immission level concept. (d) Uses a compressive (less than additive) model for the interaction of the age and noise factors. (e) The importance of high frequencies. None of the nine ‘commonly used or proposed equations for the assessment of hearing handicap (“disability” in WHO and UK terminology) for conversational speech’ that are given in ISO 1999: 1990 includes any frequency higher than 4 kHz. (f) Risk of hearing handicap decreasing with increasing duration of potentially hazardous noise exposure:

6.3 Risk of hearing handicap . . . NOTES . . . With some data bases for HTLA and certain choices of frequency combinations and fence, the risk of hearing handicap due to noise may decrease after a number of years of exposure. This is an inherent disadvantage of the concept ‘risk of hearing handicap’. It should not be interpreted as if the harmful effects of noise cease to exist. The explanation is that people who have crossed the fence because of age-related threshold shifts are no longer eligible for a risk of hearing handicap due to noise.


(a) Use of ear-borne dosimeters to measure sound levels at entrance of ear canal. (b) $L_{EQ}$ in range 91 dB(A) to 96 dB(A) for platers and welders in a Swedish shipyard (Kockums). (c) Use of Békésy sweep frequency pulsed tone audiometry in hearing conservation programmes. (d) Despite using hearing protection, half of the workers had a significant hearing loss in the 2 kHz to 8 kHz range within a period of two years. (e) Despite the greater attenuation of sound by earmuffs, workers using muffs have poorer

144 Not yet endorsed by the UK.
hearing than those wearing earplugs (a paradoxical finding attributed to muffs being easier to remove, and being more likely than plugs to be removed by the worker when he wishes to communicate with a colleague).


Noise is generated by a number of domestic appliances within the home. A large number of noise spectra are presented. Such spectra can be used in conjunction with tables to determine the loudness or noisiness of sounds to calculate the reduction in intrusiveness of particular patterns and degrees of hearing loss.


The ‘loudness’ and the ‘annoyance’ of tinnitus are two distinct dimensions. What matters is ‘annoyance’ since this is what tinnitus sufferers suffer from, and this, fortunately, is the measure that responds to appropriate treatment.


(a) Frequency of hyperacusis, particularly in association with tinnitus: ‘Since 1991, > 500 tinnitus patients have been seen in our center (in University of Maryland School of Medicine, Baltimore). About 40% exhibited hyperacusis in varying degrees.’ (b) Prognosis when treated: ‘The improvement in hyperacusis was observed in approximately 90% of treated (counselling and use of noise generators for tinnitus) patients.’


An example of how a doctor’s brief statement of the way in which he approaches the investigation of his patients may not describe his method in practice well. These doctors say that they adopt a neurophysiological approach to tinnitus but if one reads their article they say: ‘A detailed medical examination follows. This examination evaluates the general medical status of the patient and other potential medical problems but focuses particularly on psychological aspects of tinnitus perception.’

(a) Prevalence of HPD use: ‘Ground forces other than artillery and armoured car personnel do not wear hearing protectors.’ (b) Prevalence of impaired hearing in injured soldiers: 30% of 2415 soldiers admitted to a military hospital. (c) Severity of hearing loss: ‘over 70 db’ in cases attributable to artillery and land mines. (d) Prevalence of eardrum ruptures: 29% of the soldiers had ‘perforations in the tympanic membrane with conductive or mixed type of deafness’. (e) Symptoms: ‘deafness, tinnitus, earache and dizziness’. (f) Prognosis: 90% of cases ‘regained good hearing’; in 98% of cases ‘with conservative treatment, the tinnitus and dizziness also gradually improved’.


Similarities to tinnitus:

Acute episodes of back pain are remarkably common. There is a high natural remission rate, with about 90% of cases resolving within six weeks . . . Despite these optimistic findings the prevalence of chronic or recurrent back problems is high – present in up to 39% of adults. Much effort is expended searching for a specific organic diagnosis . . . Extensive epidemiological studies have demonstrated little or no correlation between back problems and . . . radiological signs of disc degeneration . . . Much more important are . . . psychological morbidity . . . In particular, studies in people not suffering from back pain show that potent predictors of future episodes of back pain include previous back pain . . . We now realise that, for many patients, chronic back pain is not the same as acute back pain lasting longer.


Contribution that Békésy audiometry can make to the evaluation of hearing loss.


Non-specificity of tympanogram pattern and ear pathology.


There is a need to look at durations of recovery from noise-induced temporary threshold shift to use as index of noise-induced permanent threshold shift.

Confirming that gender is a factor that influences hearing threshold levels.


A particular Békésy audiometric pattern that points to a nonorganic hearing loss.


Normal inability to detect changes in sound intensity as small as 1 dB, even when using sensitive sophisticated testing procedures.


(a) Measured thresholds of hearing: ‘the threshold values obtained with 5-dB steps were slightly higher than those obtained with 2-dB steps. In theory, this difference should be half of the difference between the step sizes, i.e. 1.5 dB. The figures obtained were 1.52 in the normal group and 2.10 in the cochlear group, which are in reasonable good agreement.’ (at p. 54). (b) Reproducibility of measured thresholds: ‘in the cochlear group (the published audiometric picture is compatible with noise damage of one sort or another), a significantly smaller standard deviation was obtained with 2-dB steps at 3,000 Hz and 4,000 Hz. This could be due to a lower difference limen for intensity (DLI) at these frequencies’ (at p. 54).

All audiograms were obtained with a clinical audiometer type Madsen OB822, calibrated according to ISO 389 (1985) and fulfilling the requirements of IEC 645 type 1 (1979). Earphones type TDH49 with cushions MX41/AR and a standard headband were used. The measurements were performed in a sound-insulated booth, whose ambient sound level was lower than the levels specified in ISO/DIS 8253 (1984) and thus fulfilled the criteria for threshold measurements at 0 dB HL. (at p. 52)


Attitude is a major factor in determining the degree of annoyance occasioned by environmental (external) noise. It would therefore be reasonable to expect that attitude will be a major factor in determining the degree of annoyance occasioned by internal noise (tinnitus).

(a) First MRC epidemiological study of the hearing of workers in noisy industries (during 1948 and 1949). ‘The National Physical Laboratory gave their cooperation and carried out a full series of noise level measurements.’ Hearing was examined using pure-tone audiometry. Examples are given that show high frequency hearing losses; unfortunately the author said nothing about excluding workers who had been exposed to gunfire and many would have been of military age in World War II. Consequently there will always be a concern as to whether or not any of the hearing defects, particularly the sharp 4 kHz notches, might have resulted from gunfire. (b) No mention of an acute, as opposed to the chronic, form of ONIHL. (c) Tinnitus comes early in the course of hazardous occupational noise exposure and is not a prominent feature of hazardous occupational noise exposure.


An explanation of how a sensorineural hearing loss might be associated with earpits when the inner ear is generally considered to follow an entirely different line of development from that of the outer ear. A genetic defect in ‘earpit-deafness’ syndrome may interfere with normal development of neural crest with secondary involvement not only of the branchial system but also of the melanocyte migration to the stria vascularis of the inner ear.


In the development of science ‘the obvious has usually turned out to be wrong’ (at p. 6).


When differences are observed between ascending and descending continuous test tone thresholds the reverse sweep threshold is always the poorer and is associated with retrocochlear lesions.


Industrial audiometry possessing ‘a strong additional attribute in that it contributes significantly to employee education in the hazard represented
by industrial noise, and is capable of changing behavioural patterns; in particular hearing protector usage’ (at p. 508).


Noise levels in industry. Sound levels have been measured for representative samples of a wide range of manufacturing industries in the USA. Sound levels are expressed in dB SPL (not in dB(A)) and loudness is expressed in sones.


Non-specificity of audiograms of patients diagnosed as having ‘pure’ presbycusis (after ‘strict criteria’ had reduced the total group by 92%). Some patterns were indistinguishable from those of occupational noise-induced hearing loss.


Hearing loss in miners due to hazardous vibration exposure.


A type of sudden hearing loss, with features of endolymphatic hydrops, which comes on in the course of noisy industrial work. It is associated with use of percussive tools. A vibration factor.


Occupational noise-induced hearing loss develops and is complete within early years (three) of hazardous occupational noise exposure.


High-frequency audiometric fall off in jute weavers is steeper than that predicted by NPL Ac 61 model. Hypothesizes that the NPL model may have been in error due to sampling/selection methods.


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145 Concerning vibration-induced hearing loss in miners.
Tinnitus in jute weavers. A questionnaire used in a study of jute weavers (at p. 190) indicated that no information would have been elicited in respect of tinnitus.


The way in which the ear conducts its task in hearing: an active way (see the elegant demonstration of the active motion of outer hair cells by his colleague in University College London, Professor Ashmore, at the website http://www.physiol.ucl.ac.uk/ashmore/jfa.htm), completely unlike the passive explanation given by Békésy.


Otoscopic abnormalities (4.9% perforation; 9.9% eardrum intact but gross changes) more likely than not (53%) in some industrial populations in the north of England. An examination of employees (some exposed to hazardous noise levels, some not) of a factory in Leeds.


Remarkable recovery is the rule after blast injuries of the ear (as observed after a 5 lb bomb exploded in March 1972 in a crowded restaurant): ‘Almost everyone experienced temporary severe deafness . . . In most instances, this severe deafness was short-lived and recovered fairly quickly . . . Almost all complained of severe tinnitus immediately after the blast’ (p. 135). ‘The authors have been most impressed by the ability of the ear to recover from blast injury.’


Hearing loss due to head injury may occur in cases where there has been no loss of consciousness.


First to propose the term ‘apoptosis’ for a ‘hitherto little recognised mechanism of controlled cell deletion’.


*Advantageous* aspects of an acquired hearing loss: there are a number of beneficial effects, of which the most common is reduced disturbance by
unwanted sounds – a reduced nuisance effect of noise. Positive experiences include reduced disturbance by unwanted sounds (33% of those listing positive experiences), successful communication strategies (30%), affinity for other hearing-impaired and disabled people (22%), perceived self-development (16%), use of hearing loss to self-advantage (13%).


One shot only required to cause permanent noise-induced hearing loss and tinnitus: ‘A single acoustic trauma can be the cause of lasting inner ear hearing loss and tinnitus’ (at p. 156).


Clearly distinguishing between occupational noise-induced hearing loss and what has become to be known as the King–Kopetzky syndrome.


(a) Method of eliciting the history: ‘Leading questions should be avoided wherever possible. Case notes and medicolegal reports should indicate what questions were asked, their order, the answers and any information volunteered.’ (3rd paragraph at p. 93) (although this appeared in the section on tinnitus, it applies to the whole history taking). (b) Audiometry: Example 1 shows an ear where difference from one test to another for 1, 2, and 3 kHz average is 5 dB (at p. 84). (c) (i) Diagnosis must precede any disability assessment (paragraph 9.1.1); (ii) there is more likely than not to be more than one diagnosis in a given individual: ‘Note 1: diagnoses in most claimants are likely to be multiple, few having no probable element of age-related hearing loss’ (at p. 61); (iii) it is quite possible for the examiner to find that a plaintiff has a sensorineural hearing loss but he is unable to find a cause for it: ‘Note 2: SNHL of unknown origin is an acceptable and not uncommon diagnosis’ (at p. 61); (iv) methods for diagnosis: ‘A description of how that diagnosis is made is outside the scope of the present report and the reader should refer to the relevant sections of textbooks (e.g. Alberti, 1987; Hinchcliffe, 1992) and criteria for its diagnosis (Robinson, 1985)’ (at p. 51); (v) specification and, if possible, quantification of all factors contributing to any hearing loss: ‘Statement of all factors believed to be substantial (but what is “substantial”? Presumably, if “every decibel counts”, then any factor that could be operating) contributors to the measured hearing impairment . . . the statement should include an estimate of the amount(s) of occupational, leisure and military noise exposure (levels; daily durations, days per year and years; stated
dates, extent of usage and type of hearing protection’ (at p. 61). (d) What allowance should be made for the wearing of hearing protection? Attenuation values in decibels are given in Table B1 (at p. 91). (e) ‘Low fence’. A hearing threshold level (averaged over 1, 2 and 3 kHz) of 10 dB (Fig. 8.1 at p. 48) was arrived at by taking the subjective estimate of the ‘hearing ability’ of an ear, assuming that the complement of this rating was a measure of an ear’s ‘disability’, that this value can be translated into an individual’s hearing disability, and then fitting the data with a particular mathematical formula termed a Gompertz function instead of the logarithmic or power functions, which are used by psychophysicists to describe such psychophysical functions. (f) Any apportionment should ‘be in the disability domain’ (at p. 5). If this principle were to be followed, the work of the Medical Research Council (Davis, 1987) would demand that an even greater allocation should be accorded to ageing. The major difficulty with the ‘Black Book’ is that hearing disability is treated as though it were a continuous function of the hearing threshold level. This is perfectly satisfactory as a mathematical exercise in curve-fitting but it can lead to error when the result is interpreted for medicolegal purposes. When there is little or even no hearing loss, the continuous disability function is necessarily finite, suggesting, erroneously, a real disability, where in reality none exists. This difficulty was avoided in previous scaling methods by the introduction of an (arbitrary) low fence below which disability was deemed to be non-existent. But this difficulty is not new to the experimental psychological sciences dealing with subjective magnitude scaling. It was encountered in the 1950s when the particular mathematical formula (power function) that was found to describe the relationship between the subjective magnitude, for example loudness, and the physical magnitude of a stimulus, for example sound intensity, predicted that sounds at threshold, and even below threshold, would have finite loudness. The solution was to subtract the physical magnitude of the threshold stimulus from the physical magnitude of the stimulus (Scharf and Stevens, 1959). Although Habib and Hinchcliffe (1978) subtracted a value equivalent to threshold from their ‘subjective magnitude of impairment’ function, HSE Report No. 1/1987 (Robinson, 1987) would indicate 30 dB HTL (averaged over 1, 2 and 3 kHz) to be a more appropriate value. However, having regard to the work of the MRC (Davis, 1987), one can no longer consider hearing disability to be uniquely determined by the hearing threshold level (Williams, 1992). Finally, in Robinson v British Rail Engineering [1982] Court of Appeal (Civil Division) No. 489, 3 November, the Court of Appeal disposed of hearing disability/loss of amenity assessments based upon pure tone audiograms in no uncertain terms. Yet professionals in the area of hearing disorders continue to produce disability/handicap assessments
using such methods. It is so much easier (at least for adults) to ask a plain-
tiff ‘what difficulties do you have?’ That is what the courts appear to
require. Moreover such an approach is more consistent with clinical
practice.

the Royal Society of Medicine 51: 45–52.

Temporary noise-induced impairment of hearing does not betoken a
noise-induced permanent threshold shift. After adequate rest the hearing
of Shackleton aircrews returns to normal, despite 40 dB noise-induced
temporary threshold shifts at 1 kHz being produced by long flights.


Hyperbolic tangent as a mathematical function with which acousticians
would be conversant.

KLOCKHOFF I, DRETTNER B, SVEDBERG A (1974) Computerized classification of the
results of screening audiometry in groups of persons exposed to noise. Audiology 13:
326–34.

Hearing of Swedish construction workers. Out of 2932 to whom hearing
screening tests had been administered, 32% had hearing within the
normal range in both ears, and ‘More or less asymmetrical hearing loss
was found in 37% of the individuals, which may argue that there was a
considerable admixture of other etiological factors than continuous
exposure to noise’ (at p. 330).

KNIGHT JJ (1966) Normal hearing threshold determined by manual and self-recording

(a) Thresholds obtained by pulsed fixed frequency self-recording audiomy-
tery 0.8 dB more acute than manual audiometry employing a 5 dB-step
attenuator and after correcting the manual thresholds by subtracting 2.5
dB for the quantization error. (b) Calibration problems at 6 kHz.

KNIGHT JJ, COLES RRA (1960) Determination of the hearing threshold levels of naval
recruits in terms of British and American standards. Journal of the Acoustical Society of
America 32: 800–4.

Standard practice in auditory epidemiology to subtract 2.5 dB from
‘averages’ to take into account audiometer attenuator step size (5 dB).

KNOTTNERUS JA, DINANT GJ (1997) Medicine based evidence, a prerequisite for
There is a need for ‘medicine based’ studies that include, not ignore, clinical reality and its inherent difficulties. Since no individual study can include full clinical reality, meta-analyses of various diagnostic and therapeutic studies including various relevant subgroups (such as elderly patients or those with comorbidity) are indispensable.


Standardization in acoustics is not simple: ‘Acoustical standards are always difficult to establish or to reproduce, and those required in the calibration of audiometers are among the most elusive’ (at p. 104).


The possibility of having a normal ‘echo’ in cases of a profound sensorineural hearing loss.


The probability that a sportsman uses hearing protection. It is estimated that only 1% use hearing protectors while shooting.


A scheme for quantifying the *noisiness* of sound (analogous to the *loudness* of sound).


(a) Diurnal variation in assessing reactions to environmental noise.

As noted earlier, the $L_{dn}$ noise measurement procedures involve the addition of a 10-dB penalty to noises occurring during typical hours of sleep, 10 PM–7 AM. The metric, CNEL (community noise exposure level), used in the state of California, and WECPNL (weighted equivalent perceived noise level, in $PN_{eq}$ or $DB_{A}$), recommended by the International Organization of Aviation, and used in Japan and elsewhere, for noise-assessment purposes involves, in addition to 10-dB 10 PM–7 AM penalty, a 5-dB penalty to aircraft noise exposures between 7 PM and 10 PM. These penalties are based on a mixture of laboratory and field research and the general experience of acoustical consultants working on community noise problems. (at p. 640)

(b) Gender differences in susceptibility of hearing to noise damage:
male and female ears probably do not differ significantly in regard to susceptibility to NIPTS [noise-induced permanent threshold shift] . . . Robinson’s . . . finding could have been, at least partially, due to the procedure used . . . to correct male hearing levels for presbycusis. (at p. 155)

(c) Differences between thresholds measured by manual and self-recording audiometry:

With the manual instrument, the intensity at which the subject hears the presence of a pure tone no more than twice out of three, or three out of four presentations, is usually selected as the threshold level of hearing sensitivity, such as a 67–75% – say, 70% – correct criterion of threshold. With self-recording (also called Békésy type) audiometers, the threshold level is typically taken to be the level halfway between the extremes (audible–inaudible) of the recorded trace of the changes in the level of the tone. This could be called the 50% correct threshold, as distinct from 70% correct threshold of manual audiometry. Because the range in intensity from inaudible to audible levels, and reverse, on the self-recording audiometers is typically 10 dB (Rudmose, 1963), the difference between the 50% point of the level trace and the 70% correct manual threshold would be of the order of 2.5 dB, with the manual threshold being the higher of the two. Whatever the reasons might be, a difference of that magnitude has been generally found in studies of thresholds obtained by these two methodologies, as shown in Table 4.1B. (at pp. 113 and 115)

(the table lists ten studies of which all except one show an overall better threshold (averaging 3 dB) when measured with self-recording audiometry).

(d) Overall the book provides a compact current account of noise and its effects on man, but there are a number of inaccuracies.


Tables used to calculate the noisiness of a sound in noys from sound level measurements (one-third of an octave bands). The number of noys depends on the sound pressure level of the band and the centre frequency of the band, with the maximum noisiness occurring for the 3.1 and 4 kHz centre frequencies; the noisiness–frequency pattern mirrors that of the audiogram of occupational noise-induced hearing loss (Table I – Sheet 1); the implication is that the noisiness of sounds is preferentially reduced in occupational noise-induced hearing loss.


The dynamic changing nature of science. Scientific paradigms are ways of looking at the world that define both the problems that can legitimately be
addressed and the range of admissible evidence that may bear on their solution. When defects in an existing paradigm accumulate to the extent that the paradigm is no longer tenable, the paradigm is challenged and replaced by a new way of looking at the world. Thus, in respect of medicine in general, the current Zeitgeist is evidence-based medicine.


The basis for the inheritance of branchio-oto-renal syndrome.


Date since when all British medical practitioners, let alone specialists, should have known that a scarred eardrum was an abnormal structure and not a variant of the normal eardrum. ‘Scars, however, only occur after injury or suppuration’ (at p. 121).


The role of 5-HT (5-hydroxytryptamine, i.e. serotonin) in reducing response to painful stimulation.


(a) his concept of determinism:

Une intelligence qui pour un instant donné, connaîtrait toutes les forces dont la nature est animée, et la situation respective des êtres qui la composent, si d’ailleurs elle était assez vaste pour soumettre ces données à l’analyse, embrasserait dans la même formule, les mouvements des plus grandes corps de l’univers et ceux de plus léger atome: rien ne serait incertain pour elle, et l’avenir comme le passé serait présent à ces yeux.146 (p. 3)

but there was no evidence in the monograph that he believed that anyone would ever achieve that perfect knowledge.

146 ‘Given for an instant an intelligence that could comprehend all the forces by which Nature is animated and the respective situations of the beings who compose it with an intelligence sufficiently comprehensive to subject these data to analysis, it would embrace in the same formula the movements of the greatest bodies of the Universe and those of the lightest atom: nothing would be uncertain for it, and the future as well as the past would be present to its eyes.’
(b) There was consequently the need for a system by which one could reason in these areas of incomplete knowledge, and this was where probability theory comes in.


(a) Tinnitus in workers exposed to hazardous noise levels:
(i) illustration of how reported prevalence will depend on method of eliciting a response:

All the labourers examined were carefully questioned as to subjective sounds. It is not sufficient to ask whether the individual under consideration experiences buzzing in the ears, for it frequently happens that he denies it, whereas he, after patient querying, will admit that he actually is distressed by subjective sounds, which he characterizes as uproar, droning, growling, ringing, singing, whizzing, squeaking, roaring, music in the ears, etc. (at p. 68)

if the subjects in the 1958 Medical Research Council Hearing Survey (Hinchcliffe, 1961) had been pressed similarly, would the observed prevalence of tinnitus have exceeded 20% to 40% (depending on age) and have reached the 48% level recorded by Larsen for his boilermakers?
(ii) prevalence of distressing tinnitus: ‘In 5 of these cases (i.e. 4% of the total) the buzzing has been very distressing’ (at p. 69). How would this value have differed from a control group? Note that it is said that the buzzing ‘has been’ very distressing, which implies that it no longer is so;
(iii) there is no mention of delayed onset tinnitus.

(b) In an experimental study of the effect on three normally hearing individuals of industrial noise exposure (in a tank in a shipyard where riveters were at work) for 30 minutes to one hour: there was slight to considerable buzzing in the ears, which disappeared over the course of the day, and audiometric examination showed 30 to 45 dB notches at 4 kHz (at pp. 103–4).

(c) Demonstration that there could be an appreciable reversible component in the audiometric measures of occupational noise-induced hearing loss. Seven of the 30 subjects whose hearing was tested by an audiometer were retested on a Sunday (in general, the audiometry was conducted in an evening after work). One case used for illustration showed a shift of the notch peak (at 3 kHz) from 60 dB HTL to 15 dB HTL.

(d) No mention of the existence of an acute form of occupational noise-induced hearing loss.

Clinical and pathological picture of occupational noise-induced hearing loss:

Most investigators agree about the following: the occupational deafness is a nerve deafness and its pathologico-anatomical substrate is degenerative change in the organ of Corti and the spirale ganglion, beginning in the hair cells and most pronounced in the basal turn. (at p. 139)

The number of hard of hearing among workers and the degree of deafness is proportional with the intensity. It is well known for instance that deafness in weavers occurs later and is less severe than that of boilermakers. (at p. 142)

If a number of persons were exposed to exactly the same working conditions during the same number of years, the hearing of the single individual would be found to differ rather much. (at p. 143)

On the other hand I have discovered two persons with quite normal hearing after respectively 15 years’ work as a boilermaker and 14 years’ work as a rivetter. Similar cases have been reported by Bunch, Key-Aberg . . . It is generally accepted that this difference in susceptibility is due to constitutional differences, but that of course does not indicate anything. The factors underlying are unknown . . . (at p. 144)

If deafness has resulted from excessive stimulation to industrial noise, it is first evidenced by an abrupt dip in the hearing range usually near C5. This has subsequently been substantiated by numerous authors and has been observed among persons of most different professions such as boilermakers, metallists, weavers, miners etc. (at p. 147)

A C5 dip is important for the diagnosis of the initial stages. However, a C5 dip is by no means pathognomic for occupational deafness as it occurs in a number of different diseases and amongst other intoxications (tobacco, quinine, cocainism, alcoholism), syphilis, head trauma, otosclerosis and retinitis pigmentosa (at p. 148)

All authors agree as to the first sign of occupational deafness audiometrically presenting itself as a C5 dip. How is it to be explained?

The circumspect defect of hearing is not only met with in cases of occupational deafness but also in many cases of intoxication, head trauma, etc. That probably signifies that the place for perception for C5 presents a special vulnerability which decreases to both sides. The reason for this vulnerability is unknown. After numerous experiments and histological examination the place of perception for C5 in the cochlea is thought to be localised in an area lying at a distance of 8–9 mm from the basal end. (at p. 149)

The pathogenesis has such been discussed by many authors without the question, why the cochlea degeneration so often strikes C5 being explained satisfactorily. (at p. 150)


The need for the impartiality of expert witnesses:

It should be remembered that whether giving evidence as a witness of fact or as an expert witness, the role of the doctor is to assist the court and remain independent of the parties, regardless of the fact that the doctor will have been called to the court by one of them. Detached objectivity is required at all times. The following passages clearly set out what the doctor's role should be when acting as an expert:

‘As is widely known, an adversarial system of examining the merits of cases is operated in most parts of the UK. Thus the plaintiff's case is put and is supported by evidence; then, the defendant's case is similarly put and supported. It follows that a clinician may be approached by those acting for either side. In these circumstances of adversarial proceedings the clinician must keep a cool head and maintain an impartial posture. The temptation is great to give the report a bias in favour of the paymaster's client, in the not unreasonable belief that if this is not done the invitation to report will not be repeated. This temptation should be resisted; the profession of medicine is too august to be sullied by such paltry dealings. Nor should the reporting clinician make a judgement; this is for the judge – as indeed the word suggests. ‘The clinician should display the facts and the evidence as presented, and may then hazard an opinion on the medical aspects of the case’ (Foy MA, Fagg PS Medicolegal Reporting in Orthopaedic Trauma) [this paragraph is abstracted from the chapter contributed by G Bonney to the book].

'I have to say that I feel that I feel some concern as to the manner in which part of the expert evidence called for the plaintiff came to be organised. This matter was discussed in the Court of Appeal and commented on by Lord Denning MR. While some degree of consultation between experts and legal advisers is entirely proper, it is necessary that expert evidence presented to the court should be, and should be seen to be, the independent product of the expert, uninfluenced as to form or content by the exigencies of litigation’ (Lord Wilberforce, House of Lords, Whitehouse v Jordan (1981) 1 AU147 ER at 276148). (at pp. 12–13)


Relative unimportance of frequencies in the 6 kHz region for speech despite the fact that the consonants /θ/, /s/ and /ʃ/ (which belong to that particular subgroup of fricatives termed sibilants) have appreciable sound energy between 3 kHz and 8 kHz. Experimental demonstration that people with marked high frequency hearing losses (steep losses above 1 kHz descending to 50 to 70 dB at 2 kHz and 75 to 100 dB HTL at 4 kHz) can identify these sounds.

147 A misprint for ‘All’.
148 A misprint for ‘267’.
149 ‘Th’ as in thought.

(a) Recognition of noise-resistant ears. Some individuals (‘the noise-resistant fraction’) ‘retain acute HTLs in spite of noise exposure known to cause hearing loss in the majority of the population’ (at p. 1). (b) Recognition that poor hearing threshold levels are ‘not proof of a particular susceptibility to noise’ (at p. 1). (c) Pursues a novel experimental approach to studying susceptibility by looking at soldiers who have retained remarkably good hearing. It is unable to confirm that eye colour was a factor.


The diagnostic process being essentially a sequential decision-making process.


How we can distinguish various diseases and audiometric patterns: probably an extension of the way we distinguish faces one from another (a pattern recognition exercise).


Intellect is basically similar for everyone:

One of the first among those thinkers most influential upon the development of Aristotelian and Greek thought in Islam was Alkindi (d.872) . . . This interpretation . . . was to give rise to one of the most marked features of Islamic thought – the belief that there was only one active intellect for all humanity . . . (at pp. 145–6)


Distinguishing between the clinical picture and the clinical audiometric picture (Klinisch-audiometrisches Bild) of occupational noise-induced hearing loss.


Errors introduced by failing to take account of audiometer attenuator (intensity) step size: for example, reducing the intensity step size from 5

150 Occupational injury to the ears.
dB to 1 dB would improve measured threshold by 2 dB (simplistically, $2.5 - 0.5 = 2$ dB).


Acceptability of Kryter’s 1973 paper: ‘If indicated baseline corrections are used, Kryter’s risk values compare favourably with NIOSH-data.’


Arguing that science is a complex social process and that to understand how knowledge becomes accepted and ‘institutionalized’ it is necessary to understand it in its historical and cultural context.


Impossibility of expert witnesses being able to tell the ‘truth, the whole truth and nothing but the truth’ even with the information superhighway being at their disposal: ‘The Internet is growing so fast that no single human can keep up with it all’ (at p. 359).


Experiments to assess relative importance of sound duration and peak level of impact noise on hearing. Objective (electrophysiological) measurements of the hearing and microscopic examination of the hair cells of animals exposed to electronically synthesized impact noise (simulating a hammer striking a piece of metal):

> With each dB increase in the ‘duration’ series, there was approximately 1.7 dB of increase in hearing loss. For each dB increase in the peak level above 125 dB, there was an average 6.6 dB increase in hearing loss. The 125 dB exposure is just below the ‘critical level’ where the mode of cochlear damage shifts to mechanical failure.


Histopathological evidence for cochlear endolymphatic hydrops.

Evidence for activity in this field by British government establishments over 40 years ago.


A psychophysical function (in this case a loudness function) shows as a continuous curve without any evidence of a point of inflexion, or ‘knee point’; any evidence for particular, specific levels, for example a level of most comfortable loudness, or the threshold of uncomfortable loudness, will depend on implementing different experimental procedures.


Need over 20 years ago in British Columbia for special facilities for people complaining of tinnitus.


(a) Nature of the clinical examination:

The interview begins with a friendly greeting followed by a conversation during which the doctor tries to reconstitute in his mind what the patient has experienced. This is supplemented by information derived from examination of the patient’s body. The aim is to reach an explanation of these experiences, since this must precede any sensible attempt to improve the patient’s lot . . . The whole process is known as ‘history taking’; it is a complex process . . . Direct but not leading questions are permissible . . . the doctor assiduously notes the positive tests which have led him to conclusions and to the negative features which made him reject important other possibilities . . . If the account of the verbal interview ended here it would be woefully inadequate, a recipe for a deplorable standard of practice. The defect arises because: (1) from the point of view of physical diseases, no doctor is capable of consistently picking up all the clues offered to him and there is a danger of clues not being offered: (2) whether applied to physical or psychiatric disorders this technique yields a pathological lesion, a recognisable disease or syndrome and no more or less than that; it tells us nothing about the patient. There is a well-known aphorism which applies, with great force, at this point: ‘Il n’y a pas de maladies; il n’y a que des malades.’ 151 It draws our attention to the real business of our profession – to treat the whole patient . . . the ‘whole man’ includes the specific physical disorder and elements or colourings derived from his personality, fears, illusions, degree of introspection, previous experiences, level of information or misinformation, and social, cultural and economic backgrounds. If the doctor knows nothing about these matters he is acting merely as a technician.

151 There are no diseases, only sick people.
(b) Inter-examiner variability:

It might be useful to remind readers that patients only give a ‘proper’ history once. On that occasion they perceive the way the doctor organises the information and will change their interpretation of the predicament. In an interview with a second doctor they may lead him differently; they have digested the information and may present it in an altered sequence or structure or different emphasis. The doctor may consider himself completely free; in fact he is offered an organised substrate from which pre-formed ideas readily emerge, and he can be all too easily enmeshed, without knowing it, in the thoughts and imagination of his predecessor. (at p. 195)


Evidence for geographical variations in ear health within countries (Liverpool in this case having poorer aural health than the rest of the country), let alone between countries – relevant to ‘comparing like with like’.


Nature of sensorineural hearing loss in patients that is diagnosed as ‘presbycusis’. ‘Probably represent undiagnosed cases of familial or genetic related hearing loss.’


Undesirability of conveyor-belt processing of claimants. The author deplores the decline of clinical skills and emphasizes the importance of listening. It is not possible to practise the healing art if one is always in a hurry.


Basic information for doctors regarding occupational noise damage to hearing: ‘Excessive noise damages the hair cells of the organ of Corti . . . is important in industry and is a hazard of noisy hobbies such as shooting and using power tools.’ Statement illustrated by an audiogram that shows a clear-cut 60 dB 4 kHz notch with hearing threshold levels of 10 to 15 dB at the frequencies of 1 kHz and below.

How a clinician makes a diagnosis: even when a clinician says that he is adopting a ‘clinical’ approach, Lundberg argues that he is, in effect, unconsciously employing a formulation based upon his previous experience (or that of others). This formulation is statistical in nature.


Narrow Békésy audiometric excursions are characteristic of cochlear hearing losses.


The case for examining the ear with an ear microscope: ‘using ear speculas without magnification, even experienced otologists may overlook clinically important middle ear details’ (at p. 34).


A study of 1725 ears: ‘Neither air–bone gap nor acoustic reflex presence/absence gives unequivocal indication of abnormality in middle-ear sound transmission . . . ART is a considerably more sensitive indicator than ABG . . . However, a more comprehensive clinical picture is obtained when both ART and ABG are measured . . . These data show a continuum rising from 5% absent reflexes for zero or negative air–bone gap to 94% having absent reflexes for air–bone gaps greater than 30 dB.

The 50% point corresponds to an air–bone gap of about 20 dB. But over 5% ears with both normal acoustic reflexes and normal air–bone gaps showed otoscopic evidence for previous or current middle-ear disease.


Non-specificity of high-tone audiometric notch:

Typical audiograms . . . Audiogram \((d)\) also shows a sensorineural loss at high frequencies, but sensitivity is greater at 8 kHz than at 3, 4 or 6 kHz (that is the audiogram pattern shows a dip). This finding is common with sensorineural losses resulting from excessive noise exposure, but may occur for many other presumed aetiologies. (p. 251)


(a) A method of retrodicting:
As published, ISO 1999 is limited to estimating NIHL in populations exposed to noises that can be described by a duration at a single equivalent noise level. By application of the above logical extension to ISO 1999, estimates may be computed for compound exposures consisting of any number of component exposures, each described by a duration at a single level.

(b) Early rapid growth of noise-induced permanent threshold shift at 4 kHz and more so than at other frequencies: ‘The frequency of 4 kHz is deliberately chosen here and in subsequent examples to emphasise the flattening with increasing duration. For lower frequencies, this flattening is less pronounced’ (at p. 4).


The value of various tests of hearing and the balance function in diagnosing tumours of the nerve of hearing. It cites an application (by Turner, Shepard and Frazer, 1984) of a particular method of statistical analysis (clinical decision analysis) that shows that ‘none of the audiological [what he meant was “audiometric” tests]/vestibular (specifically the bithermal caloric test, i.e. running water at two different temperatures [30º C and 44º C consecutively into the ears]) tests is of much value’. He then goes on to criticize the study on a number of grounds. Nevertheless, even ‘a specialist department with relevant experience (in conducting electrophysiological examinations of the auditory nervous system) missed two cases (out of 18): a small (1 cm) vestibular schwannoma and a large congenital petrous apex cholesteatoma’ (at p. 2/12/27).


The use of a nine-question questionnaire relating to hearing difficulties and the individual’s feeling about these – indices of auditory disabilities and handicap. Comparison with thresholds of hearing measured with manual audiometry. It used 1691 subjects representative of the UK adult population. Statistical analysis of data indicated (a) little evidence for discontinuities (correlates of ‘fences’) in questionnaire audiometric threshold functions; (b) ‘hearing losses incorporating a conductive component in the better ear were more disabling and handicapping than sensorineural losses of equal magnitude’; (c) ‘localisation ability and, to a lesser extent, general hearing handicap were more highly correlated with measures of impairment in the worse ear than in the better ear’ (Abstract).

(a) ISO 389 too stringent; needs adjusting in direction of poorer hearing, with a maximum of 9 dB at 6 kHz (but see Lutman and Qasem, 1997); (b) screening general population shifts median hearing threshold levels by 2 dB at most; (c) more stringent noise exclusion criteria do not lead to an improvement in median hearing threshold levels.


Another formula relating HTLs to various factors.


Audiometric notches at 6 kHz recorded with audiometers using Telephonics TDH-39 earphones were artefacts:

When calibration was performed according to ISO 389, where the TDH-39 is measured using the IEC 303 coupler and the TDH-49 is measured using the IEC 318 artificial ear and corresponding reference equivalent threshold sound pressure levels (RETSPL) are used, there were notches at 6 kHz for the TDH-39, but not for the TDH-49. Calibrating both earphones on the IEC 318 artificial ear caused the difference to disappear. It is concluded that the common occurrence of 6 kHz notches is an artefact arising from a particular interaction between the IEC 303 coupler and the TDH-39 earphone. The results advocate a move away from the IEC 303 coupler for standardization purposes. Furthermore, replacing TDH-39 earphones with TDH-49 earphones would avoid other adverse interactions at non-standard frequencies above 6 kHz that could give misleading swept frequency thresholds.

This last comment is more theoretical in respect of medicolegal work as no medical examiner is known to use what is essentially a Békésy audiometer with the old TDH-39 earphone.


A study of subjective magnitude ratings of ‘hearing ability’ of an ear to produce a suggested scale for compensating damage to hearing. Constructing the scale involved taking the complement of the self-assessed ear’s ability magnitude and weighting the results for the two ears to produce a disability measure for the two ears, and hence the person.
The resulting data fitted with a Gompertz function.


Provision of a set of data appropriate to assessing audiograms for medico-legal purposes. Controls for hazardous noise exposure, age, sex and the socio-economic factor. There is also a practical air–bone gap rejection level of 15 dB.


Notching at 6 kHz appears to be associated with many conditions other than hazardous noise exposure.


Recovery of hearing after exposure to impulse noise is different from recovery from exposure to continuous noise.


Bone conduction thresholds in unilateral chronic otitis media (COM) are poorer than those in the contralateral ear that has no middle ear disease, but it is difficult to know how much is due to the mechanical effects of the middle ear disorder and how much is due to associated damage to neurosensory structures.


Tinnitus in coalminers (a study conducted on a colliery in Staffordshire) being unrelated to ‘deafness’, but ‘201 employees who did not attend for audiometry considered that they were suffering from a hearing loss. If this was the case, bias would have been introduced, probably in the direction of no effect.’


Tinnitus due to occupational noise exposure did not appear to have been listed in causes of tinnitus among patients in the nineteenth century despite the prevalence of occupational noise-induced hearing loss at that time.
Noise and Hearing I


Hazardous occupational noise levels to which users of home power tools may be subjected.


Noise hazards to motorcyclists.


(a) Judicial concern about inter-examiner variability. (b) The role of the judge in this matter: ‘The duty of the Judge is to ensure that the expert does not practise a fraud on the administration of justice’ (but how can the judge do this unless (i) he is sufficiently knowledgeable about the medical, technical and scientific matters in question, and (ii) he is allowed to see all the medical and scientific evidence relevant to the case in question and not just what the parties have allowed him to see?). (c) Extent to which expert witnesses are asked to alter their reports by instructing solicitors. The Lord Chief Justice refers to an enquiry conducted by the Institute of Psychiatry:

On 12 May of this year The Times newspaper contained an article headed ‘Psychologists Admit Duping the Courts’. It related to a study of more than 500 psychologists who had acted as expert witness . . . more than a quarter . . . said they had been asked to alter their reports to favour the side employing them. (at p. 639)


Causation: evidence for prenatal non-genetic factors and well as genetic factors.


Endorsement by lawyers of the requirement of a dose–response relationship for causation.


(a) Found that ‘other forms of deafness (defined as inability to hear a whispered voice at a distance of 14 feet)’ were 2.6 times as common as
cases of ‘nerve deafness’. The latter group would have included not only cases of occupational noise-induced hearing loss but also other causes of sensorineural hearing loss. Thus, in these weavers, conditions other than occupational noise-induced hearing loss would have been about three times as common as occupational noise-induced hearing loss. (b) There is no mention of tinnitus, let alone of it being a problem, in the 1011 weavers he had examined, and these people would have been exposed to an $L_{eq,1}$ of the order of 102 dB (A) for a working lifetime; it might be argued that McKelvie did not think about tinnitus, but, in his acknowledgements, he specifically mentions FH Westmacott who had said ‘[t]innitus is invariable’ when he had addressed a meeting a year before McKelvie conducted his study. It would be most likely that, when Westmacott discussed his project with him, he would have suggested that, if he had not already thought about it, he should look at the prevalence and severity of tinnitus in the weavers.


(a) Tinnitus associated with occupational noise-induced hearing loss. ‘Tinnitus is not a feature of trade deafness’ (at p. 402). This paper would have been based not only upon his clinical experience in industrial Lancashire but also on the information gained from examining over one thousand weavers. (b) Need for examiners to be able to communicate with the workers: ‘A knowledge of the Lancashire dialect is a useful asset in testing weavers in this county’ (at p. 402).


Even with noises outside the body, one could not predict any annoyance attributable to the noise from its physical properties.


Antiquity of compensation for occupational noise-induced hearing loss. ‘Compensation has been paid for many years to those whose hearing loss has been damaged by excessive noise. The Romans financially compensated their armourers as they recognised that working with metal resulted in hearing loss.’

Relevance of syndromes: ‘The authors of this monograph are keen observers and ardent students of disease in the best tradition of Jonathan Hutchinson, Parkes Weber, and other clinicians of an earlier generation . . . The careful study of exceptional cases can contribute importantly to medicine.’


(a) Position of earpit: five photographs that show the location of earpits.  
(b) Audiometric picture: five of the 12 audiograms show notches at 3 kHz or 4 kHz, but there was no suggestion that notching could be attributed to hazardous noise exposure.


Abnormal auditory adaptation as a feature of tumours of the nerve of hearing.


Description of the automated fixed-frequency audiometer for hearing conservation programmes (subsequently referred to as the Rudmose audiometer).


Aircraft noise levels were sufficiently high to provoke spontaneous comment by even the stoical members of élite military units. (a) Fixed-wing aircraft (for example Lockheed Hercules) noise: ‘We flew out from the operating base on a C130 . . . There was too much noise for talking. I put on a pair of ear defenders and got my head down’ (at p. 68). (b) Rotary wing aircraft (for example Chinook helicopter – Boeing-Vertol CH-47) noise:

Nobody flies Club Class in a Chinook. The interior was spartan . . . There were no seats, just non-slip flooring to sit on . . . As the Chinook lifted, its downwash created a major sand-storm . . . All the time, there was the deafening zsh, zsh, zsh of the rotor blades. Not much was said between ourselves because of the noise. (at pp. 82–84)

I could tell by the grind of the blades that the heli was manoeuvring close to the ground...the noise was deafening. (at p. 91)

No mention of wearing hearing protectors (nor would there have been any in this situation).
Date (1902) when the medical profession in the UK should have known that military personnel would sustain noise damage to the hearing as a result of using guns:

Gunnery practice, likewise, may, through the effects of concussion, predispose to deafness. For those in the Services who are obliged to be present at gun practice sound deadeners are of use . . . Ward Cousins has also devised a useful ‘sound deadener’.

The same text also mentions that tinnitus may result from ‘the concussion from gun-firing’. Thus even at the beginning of this century the military in the British Isles should have known that gunfire could affect hearing, that something could be done about it, and that hearing protectors were available to protect hearing.

A longitudinal audiometric study on former military personnel who had sustained acoustic trauma. It supports the argument that the effects of noise and ageing are additive, but data indicate that may be less than additive (a compressive effect) by about 2.5 dB at 4 kHz, and simple addition falls short by about 3 dB at 1 kHz.

The Australian scheme for compensating occupational noise-induced hearing loss. Considers six frequencies (0.5, 1, 1.5, 2, 3 and 4 kHz). The total percentage loss of hearing is obtained by adding the percentage loss of hearing at each frequency, which itself is obtained by considering the better and poorer threshold at each of those frequencies.

It is possible to make listening tests so difficult that even individuals within the normal range of hearing will have difficulty.

(a) Procedure for assessing hearing loss:
In 1974, the National Acoustic Laboratories . . . issued a new procedure [it uses six frequencies 0.5, 1, 1.5, 2, 3 and 4 kHz] for evaluating percentage loss of hearing . . . This was accepted in 1975 by appropriate committees of both the Otolaryngological and Audiological Societies of Australia as the best available procedure for assessing hearing loss on a percentage basis and was adopted in the same year by the Commissioner for Employees’ Compensation and, in a slightly modified form, by the Workers’ Compensation Committee of New South Wales. It was tested and found acceptable in compensation court cases in Victoria in 1976 and South Australia in 1977 and since then percentage loss assessments obtained with this procedure have been widely accepted by the authorities responsible for the administration of the various workers’ compensation statutes. (at p. 902)

(b) ‘Low fence’: the HTL must reach 20 dB in the poorer ear for the first five frequencies and 25 dB at 4 kHz. (c) Even though Australia is a common-law jurisdiction, there is a paucity of case law because ‘many difficulties confront workers who sue for damages for hearing loss’ (at p. 900) – hence the dearth of professional experience derived from case law that can help expert witnesses in UK in this field.


The possibility of medical examiners giving misleading reports in medicolegal cases: ‘Over half of doctors would deceive insurance companies to obtain coverage for their patients [or to receive compensation] . . . In all 75% of the doctors described themselves as patient advocates . . . 57% admitted to lying sometimes.’


Characteristics of tinnitus in Canadian claimants. Features of tinnitus in this select group (claimants) were different from those of tinnitus seen in other groups. ‘The reason for these differences is unclear, although the possibility of financial motivation by some claimants is raised.’


The most eminent of doctors can get it wrong:

The Duke de Blacas, French Minister to Austria, was very ill and Doctors Malfatti, Türckheim, and Wirer, the first physicians in Vienna, diagnosed a disease of the liver and ordered him to Carlsbad. Skoda was called into consultation, made a diagnosis of aneurysm of the abdominal aorta, and said the patient would die in a short time. Skoda’s prediction was soon fulfilled and the autopsy confirmed the diagnosis. (pp. 610–11)

Condition of the circulation as a factor influencing the state of the hearing. A comprehensive study (encompassing clinical, audiometric and pathological data) of 40 patients aged 50 years or more. The degree of hearing loss and the extent of degenerative changes in the inner ear is correlated with pathological narrowing of the main artery going to the inner ear.


In Israel, tinnitus being more of a problem in cases of acoustic trauma (as opposed to occupational noise-induced hearing loss). This needs to be read in conjunction with paper by Cahani, Paul and Shahar (1983). These Israeli papers concerned younger adults and one paper gave the information that all were males and in 76% of cases the frequency with the greatest loss was 6 kHz. The cases would have been collected in the decade after the 1973 war. We would therefore consider that the cause was primarily attributable to gunfire. Indeed their cases were referred to as being due to ‘acoustic trauma’.


Scientific basis for ENT:

The term ‘evidence-based medicine’ has been much used in the health care debate in the 1990s. The concept that everything done in medicine should have proof has been taken up as a mantra not only by politicians but also a considerable body of the medical profession. Indeed, a new journal, Evidence Based Medicine, has been introduced in response to this wave of enthusiasm. Those who have been in the profession of medicine, and especially surgery, for any length of time, know that basing every action on previously published proof is virtually impossible. Yet to speak against evidence-based medicine is akin to saying that the king has no clothes [at p. 152] . . . Our conclusion, therefore, is that on the basis of examination of 5000 articles in leading ENT journals, ENT is not an evidence-based specialty . . . the same might be applied to all surgical sub-specialties since there is a fundamental difference between the evaluation of medicines as opposed to surgical procedures. (at p. 156)


Another syndrome similar to the BOR syndrome but no kidney abnormalities and hearing loss characterised by a conductive component, which could be attributed to the syndrome or due to some unrelated middle ear disorder; no evidence for any inner ear developmental anomaly.

Suggests that central hyperacusis, in contrast to peripheral hyperacusis, reflects a 5-HT (5-hydroxytryptamine, i.e. serotonin) disorder.


The role of 5-HT (5-hydroxytryptamine, i.e. serotonin) in the control of anxiety.


The nature and value of speech audiometry.


A useful glossary of terms in the broad field of audiology, which supplements the glossary given in this volume.


A Japanese method of obtaining what is termed an effective loudness level. The effective loudness level means that the ‘strength’ of tinnitus is expressed on what is termed the phon scale except that the reference zero is 0 dB on the audiometer scale instead of 0 dB re 20 micropascals. The phon scale takes into account the way that change in frequency (pitch) affects loudness, but not the way that change in intensity affects loudness. The effective loudness level scale has yet to be validated and shown to be of value in the assessment of tinnitus in the individual. A major criticism to be directed at this Japanese study is that it does not consider individual differences in loudness perception. A dismissive approach to this matter perhaps reflects cultural differences. A common-law system such as in England, with its emphasis on the individual, does not exist in Japan. Moreover, as the British Medical Journal has pointed out, the Japanese legal system is not exactly plaintiff orientated.


(a) Effect on older plaintiffs giving medical, social and occupational histories. (b) Possibly relevant to quantum of compensation for loss of amenity if based upon an individual’s perceived quality of life: ‘memory for both the past and the future generally declines with increasing age, but this is neither universal nor inevitable’ (at p. 459).
Social and/or psychological factors being responsible for observed changes in working efficiency when physical factors are changed: increased output when illumination increased in Western Electric’s Hawthorne\textsuperscript{152} factory but output also increased when illumination is decreased – an effect attributed to workers perceiving that management was taking an interest in them. Similar effects reported by the Committee on the Problem of Noise (1963).

A committee of research academics may be wrong (at p. 53):

\begin{quote}
Sir Howard Florey (developed Alexander Fleming’s penicillin discovery) . . . had applied for help to a committee of high-ups who . . . pronounced that the future of antibacterial therapy lay with synthetic organic chemicals . . . and certainly not with fungal or bacterial extractives that seemed to belong to the pharmacopoeia of \textit{Macbeth}, Act 4, Scene 1.
\end{quote}

In considering the design of hearing aids, MRC decided that ‘a cut-off above 4,000 c/s was not detrimental to intelligibility’.

A comprehensive review (based upon a review by Walford, 1984), with about 500 references, of noise hazards arising from living in this day and age, including some useful data on both civil and military occupational noise exposure. It uses a value termed the ‘noise immission rating’ which is derived from estimates of hazardous occupational noise exposure, and gunfire exposure (at p. 98); ‘It is pointless to dwell on actual noise levels produced by sports guns as there is general agreement that firearm noise is definitely damaging to unprotected hearing’ (at p. 45).

The extent to which clinicians do or should make use of statistical methods in diagnosis:

\begin{footnote}
\textsuperscript{152} Hence the name of the phenomenon.
\end{footnote}
There is no convincing reason to assume that explicitly formalized mathematical rules and the clinician’s creativity are equally suited for any given kind of task, or that their comparative effectiveness is the same for different tasks. Clinical practice should be much more critically examined with this in mind than it has been. (at p. vi)

These comments are pertinent to the diagnosis and assessment of occupational noise-induced hearing loss.


Previous noise exposure as a factor in causation of tinnitus: ‘80% of the men had had exposure to loud sounds’ (at p. 20). However, it is not clear what ‘exposure to loud sounds’ meant. Apparently this information was based upon a questionnaire and the actual questions were not included in the publication. There was no control population.


A feature that distinguishes patients suffering from tinnitus from those who are aware of tinnitus (but are not troubled by it) is the presence of depression.


Characterizing and redefining what was previously referred to as the ‘earpits-deafness syndrome’. Kidney abnormalities may be asymptomatic.


Use of Békésy audiometry to track comfortable loudness levels for continuous and pulsed test tones.


(a) Recognition that, in hearing compensation evaluation, the medical expert is bringing his knowledge of pathology to bear on the matter. ‘Hearing compensation evaluation as a consequence of industrial noise exposure can be accomplished most effectively with cooperative professional interaction – a physician who is expert in diseases and pathology of the auditory system’ (at p. 391). (b) Status of tinnitus in the state of New York’s provisions for occupational noise-induced hearing loss: none (at p. 398).
Although expecting two medical reports that purport to tell ‘the truth, the whole truth and nothing but the truth’ to contain the same facts and the same logical deductions, one cannot expect them to be identical word for word because of difference in style, and even this may be subject to intra-individual variability: recounts a university candidate who, on being asked by the examiners ‘to write a Greek prose composition . . . gave them two versions, one in the style of Thucydides and another in the style of Herodotus.’ (And he did so in half the allotted time.)


Hazardous occupational noise exposure as a cause of tinnitus. It was not possible to establish a gradient (‘dose–response’) between prevalence and noise level.

(a) Experimental determination of what would now be termed ‘the minimal detectable shift in auditory threshold’. This is neither the threshold of auditory disability nor of handicap. (b) A ‘low fence’: a doctrine that ‘every decibel counts’ is enunciated but neither a claimant nor a medical examiner would be able to detect a one-decibel shift in hearing threshold level no matter what the cause. The importance in accepting the doctrine is in respect of the prevention of hearing disorders, no matter what the cause. It would also be relevant to apportionment exercises.


No significant difference between the various earphones.

The basis for clinical diagnosis is the same as the basis of chess playing: ‘Critical skill is pattern recognition. The stronger the player the larger the range and complexity of patterns that he can recognise and interpret. A grandmaster holds about 100,000 patterns in his head’. (Only when a diagnostic computer at the level of IBM’s Deep Blue 2, which beat
Kasparov, is used will the scientists be able to do better than diagnosticians as their skill is also based on pattern recognition.)


An explanation concerning high frequency hearing impaired people who do not have a hearing disability: they make use of the low-frequency energy in, and the duration and intensity of, higher frequency speech sounds. In fact it would appear that people can identify /f/ and /θ/ correctly more often when listening to speech coming through a low frequency (pass band of 200–600 Hz) system than one passing frequencies above 2 kHz only.


Experimental demonstration that, at least for a short time, when noise level increased, work performance and production also increased.


(a) For intermittent exposures there is variability of time and intensity trading: neither 3 dB nor 5 dB may be correct. The trading relationship can be anywhere between 0 dB and 8 dB. The actual trading ratio is most likely to be a function of the intensity of the noise because at relatively low sound levels one can tolerate excessively long exposure durations but at high levels noise is so damaging that increasing by 3 dB or 5 dB, even with the duration halved, would be associated with an increased hearing loss. (b) If no high-frequency hearing loss occurs due to hazardous occupational noise exposure no low frequency loss will occur either.

**MINISTRY OF LABOUR** (1963) Noise and the Worker. London: HMSO.

Date (1963) when employers ought to have known that industrial noise was a hazard to hearing and that they should and could be doing something about it.

**MINISTRY OF PENSIONS AND NATIONAL INSURANCE** (1965) Incidence of Incapacity for Work in Different Areas and Occupations. London: HMSO.

Coronary heart disease was twice as common in coalminers (face workers) as in a comparable, physically active population (agricultural
workers), and psychosis and psychoneurosis was more than four times as common.


(a) The way in which clinicians approach the diagnosis of sensorineural hearing disorders – not solely by looking to audiometric tests, but by looking at information derived from sources other than audiometry. (b) The probability distribution of biological measurements conforms to a Gaussian (‘normal’) distribution. The authors’ Figure 1 shows the size distributions of tumours of the nerve of hearing for two groups of patients and neither conforms to a Gaussian distribution.


A pre-audiometric scale of degrees of hearing disability and of handicap resulting from impaired hearing.


Impossibility of predicting outcome of a disability. ‘Decades ago, doctors told Professor Hawking that his life expectancy was very limited because of his disability.’


Accentuating effect of chemicals among petroleum refinery workers.


Presentation of age-specific reference ranges for hearing levels, and change in hearing levels, for men and women at 0.5 kHz, 1 kHz, 2 kHz and 4 kHz, constructed from data obtained from persons in the Baltimore Longitudinal Study of Aging. Percentile curves provide a reference for detecting when a person deviates from a normal pattern of change, thus helping diagnose problems with hearing, or in monitoring hearing in occupational settings. These percentiles are the first reference curves that (a) provide standards for hearing level changes over periods of up to 15 years, (b) account for age differences in the distribution of hearing levels, and (c) are based on data from persons who have been systematically screened for otological disorders and evidence of noise-induced hearing loss.

Mathematical techniques (specifically, using a linear mixed-effects model) for constructing age-specific percentiles that do not have constant variance and may be skewed.


(a) Relevance of epidemiology to medicine: ‘Epidemiology is the basic science of Community Medicine’ (at p. 264). (b) Implicit acceptance of social factors: ‘Seeking to comprehend the social and biological forces expressed in the people’s health, epidemiology is a ‘generalist’ science, concerned with causes as much as with processes of health and disease’ (at p. 264). (c) Social class as a barrier for medical examiners communicating with claimants: ‘So 80–90 per cent of the future doctors were middle-class, about 70 per cent of their patients – the general population – then were in lower classes. Such social distance may produce real difficulty . . . To communicate effectively and get a good history . . . he must study the patients’ attitudes and ways of living and learn about them as the good physician does’ (at p. 54; footnote). (d) More circulatory, mental and other illnesses in coal miners (quotes Ministry of Pensions and National Insurance (1965) data) (Table 7.3 at p. 152).


(a) Some plaintiffs’ hearing loss is identical to what British otologists would diagnose as ‘sensory presbyacusis’ (at p. 25). (b) The pattern and magnitude of the reversible component in endolymphatic hydrops (at p. 159). (c) Non-specificity of 4 kHz audiometric notches (occurrence in endolymphatic hydrops) (at p. 154). (d) High frequency hearing losses may occur in endolymphatic hydrops (at p. 154). (e) The cause of sudden hearing loss (in a total of 218 patients): the most common diagnosis was ‘idiopathic’ (59 cases), next ‘viral’ (25 cases), of which mumps was the commonest viral cause (14 cases).


(a) An approach to the assessment of an individual case. Irrelevancy to diagnosis of mathematical models developed by statisticians (‘since they [the statisticians] have never seen the diagnostician at work the models are hopelessly unrealistic’) (at p. 8). (b) Many meanings to the word ‘normal’, ranging from the clinical to the statistical (at p. 124).

Experimental study of the effects of exposure to a variety of weapons on the hearing of both normally hearing and impaired hearing subjects, including the authors.


An apoptotic and a non-apoptotic type of hair cell death following noise exposure.


(a) Types of evidence underpinning clinical guidelines: (i) ‘randomized controlled trials’; (ii) ‘other robust experimental or observational studies’; (iii) ‘more limited evidence but the advice relies on expert opinion and has the endorsement of respected authorities’ (at p. 16). (b) Key attributes of clinical guidelines. They should be: (i) valid – leading to the results expected of them; (ii) reproducible – given the same evidence and methods of guideline development, another group of developers will come to the same results; (iii) reliable – given the same clinical circumstances different health professionals interpret and apply the guidelines in the same way; (iv) cost effective – leading to improvements in health at acceptable costs; (v) representative – by involving the contribution of key groups and interests in their development; (vi) clinically applicable – patient populations affected are unambiguously defined; (vii) flexible – by identifying exceptions to recommendations as well as the patient preferences to be used in decision making; (viii) clear – unambiguous language is used and readily understood by clinicians and patients; (ix) reviewable – the date and process of review will be stated; (x) amenable to clinical audit – they should be capable of translation into explicit audit criteria (at p. 14).


The National Health Service Management Executive ‘wishes to see better use made of research-based evidence about clinical effectiveness’.

Prediction of compensation for aircraft noise annoyance:

NPL’s acoustics and IT experts collaborated to design and write ‘Airnoise’ software . . . [It] takes description of aircraft types and flight paths, and calculates the appropriate noise contour plots. This contour information is used . . . in defining zones of eligibility for compensation payments for residents living near airfields.


The way in which lawyers work to discredit the best of medicine: ‘the barristers spent much time trying to discredit my evidence on the grounds that I was an academic physician not used to the hurly-burly of acute medicine’.


Low-frequency tinnitus is not to be attributed to hazardous occupational noise exposure. Tinnitus that is associated with noise damage can be matched to a frequency of 3 kHz and above; tinnitus that is matched to a frequency of less than 1 kHz is to be attributed to factors other than noise. (This is because the tinnitus frequency relates to the frequency where the hearing loss is at a maximum; if the hearing loss is not to be attributed to noise then the tinnitus cannot be attributed to noise either.)


The scale of the problem in the UK: ‘A reasonable assessment is that at least 2 m. workers in the UK have been exposed to excessive noise for at least a significant period during their employment’ (p. 2). ‘The number of claims so far received by insurers is not known either but it could well be in the region of 200 000’ (p. 2). The number of workers claiming under the Department of Health and Social Security (DHSS) scheme since it was established in 1974 appears to have averaged less than 900 per annum over the first eight years, but with an initial value that was double that figure, and falling to a third of that figure by the end of that period, the much smaller numbers under the DHSS scheme being attributable to the very stringent entry requirements for that scheme.


Introduction of generalized linear interactive modelling, the statistical technique that was used to analyse data obtained in the National Study of Hearing.
References


The relevance of head injury in cases of hazardous occupational noise exposure. In a study of more than 100 000 noise-exposed workers it was found that a history of head injury was more important in predicting ‘speech impairment and handicap’ than was noise immission level (occupational noise ‘dose’).


The standing of the ‘Black Book’ with the British Society of Audiology:

Council wishes to clarify its position on the document Assessment of Hearing Disability (the ‘Black Book’). At the Council Meeting on 11th December 1992 it was agreed that it was no longer appropriate to endorse this type of document and Council withdrew the Society’s previous endorsement of the ‘Blue Book’. In the light of more recent scientific research and literature on this subject, the British Society of Audiology welcomes the Assessment of Hearing Disability (the ‘Black Book’) as a significant advance on its predecessor, (the ‘Blue Book’) Minute 93/03.


An increasing number of people are affected by depressive illness. This item cites a report of the Centre de Recherche, d’Étude et de Documentation en Économie de la Santé (CREDES) to the effect that the prevalence of depression has doubled in France over the past ten years.


Biological bases of susceptibility:

American scientists have identified the flaw that allows lung cancer to develop in smokers. The smoke causes damage to cells, but machinery exists to detect this damage and put it right. Only when this enzyme-based repair mechanism is damaged does cancer occur, the researchers from Harvard University report in Current Biology. Those who smoke for a lifetime without developing cancer may, therefore, simply be those lucky enough never to lose the repair enzyme in any of their lung cells.

NEWS ITEM (1999a) Join a club to slim, say the experts. Metro (28 May), p. 9.

What the clinician considers to be normal or abnormal does not correspond with what statisticians consider to be so when such a decision is based upon the distribution of a particular measure for the general population and whether a criterion of ‘normal limits’ or ‘clinical limits’
(the 2\(1/2\) and 97\(1/2\) percentage points to the distribution for the general population) is used: ‘26% of women and 17% of men . . . [are] now clinically obese’ (compare with Uimonen et al. 1999).

**NEWS ITEM** (1999b) Signal to ET shows we are only human. The Times (24 May), p. 11.

Even the highest intellects, and even when computer assisted, are subject to error: there were two simple errors in a 23-page long message being beamed to outer space to tell alien life that there are intelligent beings on planet Earth. (On this basis one might expect to find, and, we hope, excuse, 26 errors in this document.)\(^{153}\)


Attention is now being paid to occupational noise problems in developing countries.


(a) Increased loudness tolerance in people working in intense industrial noise: ‘In persons regularly exposed to industrial noise the limit of discomfort is generally found to be shifted to considerably higher sound levels’ (his Figure 1 indicates that this shift is around 40 dB – equivalent to a 16-times greater loudness) (Abstract). (This phenomenon provides the more likely explanation of statements by occupational noise-induced hearing loss claimants that their wives complain about the television being too loud.) (b) This shift disappears within two years of the individual ceasing to work in noise: ‘in 18 persons with noise-induced hearing loss who had not been exposed to industrial noise for at least 2 years . . . [there was] a normal or even decreased difference’ (pp. 173–4). Unfortunately the study did not appear to have a matched control population that had never had any industrial noise exposure.


\(^{154}\) Superseded by National Institute for Occupational Safety and Health (NIOSH) (1996).
(a) Noise exposure limits: recommended REL of 85 dB(A) for occupational noise exposure. (b) Exchange rate for calculating time-weighted exposures to noise: recommended a value of 5 dB(A). (c) A significant threshold shift in hearing conservation programmes considered to be ‘any threshold shift (to a higher threshold) that equals or exceeds 10 dB at 500, 1000, 2000, or 3000 Hz, or 15 dB at 4000 or 6000 Hz in either ear’. (d) Age corrections to audiograms applied.


(a) Contemporary risk assessment techniques incorporating the 4000 Hz audiometric frequency in the definition of hearing impairment reaffirm support for the 85 dBA REL (the excess risk of developing occupational noise-induced hearing loss for a 40-year lifetime exposure at the 85 dB(A) REL is 8%) but it is recommended that hearing conservation programmes be used for workers whose noise exposure is 82 dB(A) or more. (b) Exchange rate for calculating time-weighted exposures to noise. It recommends a value of 3 dB(A). (c) Age corrections to individual audiograms are no longer recommended because they ‘would delay intervention to prevent further hearing losses in those workers whose hearing threshold levels have increased due to occupational noise exposure’ (the criteria are provided by the DHHS in accordance with the US Occupational Safety and Health Act 1970 to enable the Secretary of Labor to formulate health and safety standards – specifically, to organize hearing conservation programmes in industry). (d) The document uses the term ‘significant threshold shift’ to define what should be considered to be meaningful deteriorations in hearing threshold level, or, rather, what merits further investigation. (e) It recommends derating the noise reduction rating (NRR) for earmuffs, formable earplugs and all other earplugs by 25%, 50% and 70%, respectively; this variable derating scheme, as opposed to the Occupational Safety and Health Administration’s (OSHA’s) straight derating scheme (by one half), takes into consideration the performances of different types of hearing protectors. (f) No mention of tinnitus.


Apoptosis is not restricted to ageing processes in the internal ear but occurs during its early stages of development.
(a) ‘Normal hearing’:

strict standards . . . should not be taken to represent the universe of ‘normal hearing’. Wheeler and Dickson (1952) recognized this in presenting the data which largely dictated the British standard.155 Their description of the thresholds as representing ‘normal good hearing’ [my italics] is an acknowledgement that the standard typifies not the norm of hearing but an extreme aspect of that norm. (at p. 184)

The assumption that elevation of threshold is a sign of reduction of hearing ability necessarily leads to the conclusion that elevation of threshold must imply a departure from normality when of course all that it may mean is a departure from good. One might still report normality of hearing because, of course, normality of hearing can mean anything from good hearing to adequacy of hearing for one’s general life purposes. (at p. 183)

(b) ‘Low fence’:

Two concepts apply to the ‘limits of normal’: the limits of variability around an audiometric norm and the point of ‘beginning impairment’ . . . best illustrated by Beasley’s analysis of the USPHS156 data . . . up to a level about 15 dB above the modal value lie roughly 98% of the values obtained from ears reported as ‘normal’ . . . [The] level of 15 dB (ASA)157 has therefore been taken as the upper limit of the normal range for these three0.5, 1 and 2 kHz frequencies (Davis, 1960, p. 257) . . . This was the ‘low fence’: a construct that (as can be seen) had both biological and administrative meaning . . . The purely administrative nature of the ‘low fence’ becomes apparent when we note that with the switch to ISO zero (on average about 10 dB lower than ASA) the ‘low fence’ was fixed at 25 dB (ISO) . . . The original concept of a ‘low fence’ has thus been contaminated, and agencies in different parts of the world feel free to fix its limit according to administrative or actuarial convenience. It is quite openly recognised in the United Kingdom, for example, that the fence, 50 dB ISO average at 1, 2 and 3 kHz, is at that level to limit claims so that the public purse is not overstretched . . . The fence principle becomes confused when age-related threshold levels are taken into account . . . For if the ‘fence’ is seen as the ‘normal’ limit, then of course that limit must change with increasing age.


An internationally approved list of anatomical terms that preceded the Terminologia Anatomica.


155 And, subsequently, the international standard.
156 United States Public Health Service.
157 See the old American standard, which was about 10 dB less sensitive than the current British and international standards.
158 0.5, 1 and 2 kHz.
The importance of the clinical examination in otology.

The practice of medicine demands the taking of an accurate history and carrying out a careful clinical examination. This principle applies to otology as much as to any other branch of medicine, and should not be forgotten in the rush for ‘high technology’ investigations [at p. 1] . . . Tuning fork tests These tests are a most important part of any clinical examination of hearing and should be performed carefully. (at p. 9)


Hazards to hearing from firing guns: 164–9 dB(A) (peak) measured for the 0.410" calibre shotgun.


No mention of an acute form of occupational noise-induced hearing loss.


(a) First comprehensive text on occupational medicine: ‘This is the first occasion on which, on the special lines indicated in this book, any adequate attempt has been made in this or any other country to deal with the conduct of trades and other occupations in respect to the dangers to life and health to which the workers are liable’ (opening sentence of the Preface).

(b) Target audience:

The language employed has been kept as free as possible from technicalities. It is confidently believed that this volume will be of considerable value, not only to medical men, whose practice brings them into contact with the working classes, to Certifying Factory Surgeons, Factory Inspectors, and employers of labour, but also to the educated public and top professional men interested in the hygienic side of industrial problems and in occupation diseases. It is hoped also that it will be of assistance to members of both Houses of Parliament. (penultimate paragraph of Preface)

(c) Occupational noise-induced hearing loss is described in Chapter LVI as ‘effects of concussion of the air’:

It may be taken as a fact based upon experience, that artisans who are exposed to such loud noises as are made in hammering rivets suffer from deafness. Boilermakers and riveters become deaf at an early age, while their comrades engaged in other kinds of work in the same shipyard do not suffer. Several young
boilermakers whom I have examined have stated that they lost their hearing at an early age. Their infirmity dated back to their 'prentice days, when as boys they were sent into the boilers to catch the rivets, and were subjected to the intense noise of hammering inside the cylinder. Workers inside sheet-iron factories are sometimes similarly affected with deafness. (at p. 752)

No mention of tinnitus.


Impossibility of distinguishing the audiometric pattern of occupational noise-induced hearing loss from that due to factors other than occupational noise damage:

The idea of stereotype patterns in familial dominant SNHL is fading. A high level of awareness of the variability of the pattern of hearing loss is therefore needed. This will improve the detection rate in true cases of familial dominant SNHL . . . It will also minimise the over-diagnosis of noise-induced permanent threshold shifts or acoustic or other trauma, especially where compensation is involved. (pp. 18–19)


(a) Noise levels in helicopters. This article cites reports that found average sound levels at ‘ear levels’ of 99.8 dB(A) for the ‘Scout’ and 100 dB(A) for the ‘Lynx’ (at p. 99). (b) The noise hazard to hearing: the author concludes:

Army aircrew are operating in an extremely noisy environment in which the principle [sic] form of hearing protection remains the use of PPE. In the past the level of protection provided in this way has not been sufficient to prevent NIHL. However . . . more recent studies have shown that NIHL in aircrew is becoming less marked and more difficult to differentiate from the natural process of presbyacusis. This is principally due to improved helmet design and awareness of the need to comply with hearing protection measures. (at p. 100)


Association of earpits with impaired hearing. Paget considered it difficult ‘to believe so great frequency of defective hearing in the subjects of aural and branchial fistulae should be casual’.


Temporary nature of tinnitus following blast injuries:
On the evening of 21 November 1974, explosions occurred in two public houses in the centre of Birmingham. Of the victims, 21 were killed (18 outright and three died later in hospital) . . . of the 111 living surviving patients, 41 had ENT complaints . . . tinnitus in 23.4% (26 cases) . . . Tinnitus was as common as deafness and, when both were present in the same patient, they occurred simultaneously . . . high pitched. Tinnitus was bilateral and continuous at onset. Later it disappeared altogether, or less often became intermittent before disappearing, usually being worse in the worse affected ear, i.e. the one facing the blast. Eventually the tinnitus ceased in all but one case.


Occurrence of mid-frequency audiometric notches due to noise trauma. Four out of 28 employees with impaired hearing had 1.5 kHz notches.


Sensorineural hearing loss associated with chronic suppurative otitis media (an epidemiological study using six centres in five countries). There were highly significant differences between bone conduction thresholds of the diseased and the control sides, and between those with bilateral disease and controls.


(a) History taking:

History taking is a major diagnostic procedure usually no less important than physical examination or investigations . . . I strongly deprecate the common practice of recording histories on standard printed sheets which are ticked or crossed on the appropriate lines or demand monosyllabic or extremely brief replies . . . Series of prearranged printed questions with a predetermined sequence cannot cater for all possible contingencies or all possible combination of symptoms, and can never assess the reliability of answers or evaluate important emotional factors. (at p. 39)

(b) The ‘art and science of diagnosis’. “Wherefore is this disease different from all other diseases?” [because it has a 4 kHz notch in the case of occupational noise-induced hearing loss] is a way of thinking which should be ingrained’ (at p. 31).

(c) Relevance of statistics:

Clinicians, whatever the depth and breadth of their mathematical knowledge, must always exhibit a healthy scepticism concerning statistics and not be mesmerized by those who have appeared to have mastered this difficult and highly specialised
branch of mathematics . . . Statistics can never be a genuine substitute for medical knowledge but should be regarded as no more than a minor, even though sometimes important, aspect of the whole spectrum of medicine. Medical statistics are like bikinis, concealing what is vital and revealing much that is occasionally interesting. Many symptoms and signs such as pain and anxiety cannot be measured in terms of numbers . . . Statistics become very absurd when used by those who want to demonstrate that something is a truth when its reality is dubious . . . The physicist Professor Dingle wrote: ‘It is a delusion that any idea which lends itself to mathematical development is thereby justified as true . . . No intelligent person would underestimate the importance of mathematics . . . but it cannot bring truth to an error. If it is applied to truth it will produce truth and if applied to error it will produce error’. (at p. 24)


‘Ultrasonic sickness’ is considered to have been ‘largely psychosomatic and engendered by the apprehension and/or fear growing out of speculative publicity about the effects of air-borne ultrasound’.


A ‘low fence’: hearing disability experienced by workers with occupational noise-induced hearing loss correlated with an average HTL (over the frequencies 0.5, 1, 2, 3 and 4 kHz) in excess of 20 dB.


Epidemiological studies indicating that rate of development of noise-induced hearing loss is faster for impact/impulse noise than for continuous noise exposures.


(a) A more conspicuous 4 kHz notch as well as better low frequency hearing than indicated by the NPL Ac 61 model. (b) Degree of hazard posed by steady state interrupted occupational noise exposure – continuous eight-hour daily exposures to a noise of a fixed sound level for five days per week. Data reviewed from eight separate studies in respect of median values indicated no effect for sound levels below 80 dB(A), but after 10 years of daily exposure to 85 dB(A), a ‘hearing loss’ of 10 dB averaged over the frequencies 3, 4 and 6 kHz, and with 90 dB(A), a 15–20 dB ‘loss’. Critics say that in three of the eight studies the workers
had not been screened for ear disease, and in one of these studies, together with two others of the eight, account had not been taken of different audiometer calibrations. Moreover, questions have arisen regarding appropriate control populations.


Interaction of knowledge and experience. Knowledge does not become readily accessible through the study of even organized facts in journals and textbooks. Efficient knowledge organization is developed primarily through repeated experiences.


(a) Deterioration in hearing threshold levels with increasing age: a parabolic formula fitted to data. (b) It provides an example of failure to read other reports before commenting (specifically in respect of 1958 MRC Survey of Hearing in a rural Scottish community). It was known at the time that many men had fired sports guns or military rifles, otherwise it would not have been possible to derive regression equations between hearing threshold level and the number of times a gun had been fired. In any case, male data were not used to derive ageing curves.


(a) Report of an equation, using the frequencies 2 kHz, 4 kHz and 6 kHz, to derive hearing disability. Although the equation, by subtracting the hearing threshold level at 4 kHz, is biologically unlikely, it gives a better prediction than those using the average thresholds for the frequencies 1, 2 and 3 kHz or 0.5, 1, 2 and 4 kHz; (b) ‘Low fence’: ‘less than 25 dB’ is equated with ‘normal hearing’.


Baltimore Longitudinal Study of Aging’s data on hearing thresholds from 0.5 to 8 kHz (collected using a pulsed-tone tracking procedure) show (a) hearing sensitivity declines more than twice as fast in men as in women at most ages and frequencies, (b) longitudinal declines in hearing sensitivity
are detectable at all frequencies among men by age 30, but the age of onset of decline is later in women at most frequencies and varies by frequency in women, (c) women have more sensitive hearing than men at frequencies above 1 kHz but men have more sensitive hearing than women at lower frequencies, (d) learning effects bias short-term longitudinal studies, and (e) hearing levels and longitudinal patterns of change are highly variable, even in this highly selected group.


Suggestion of birth cohort differences in speech perception: 70-year-old Swedish men ‘born in 1906 had a slightly lower discrimination score (4%)’ than ‘those born in 1901’ and this ‘may possibly reflect the effect of external factors such as more exposure to noise in the F 06 cohort’.


Satisfactory assessments of hearing conservation programmes can be conducted only by longitudinal studies.


Repeatability of fixed frequency self-recording audiometry; a study on 118 dropforgers: ‘use of occupational health nurses with self-recording audiometers is a satisfactory method of audiometric screening in hearing conservation programmes’ (at p. 309).


(a) Clinical and audiometric picture of noise damage to the hearing: (i)
(ii) analysis of the 30 cases presented by the author indicates that a man 
with an occupational noise-induced hearing loss would probably not be 
aware that his hearing was other than normal unless the hearing threshold 
level at 4 kHz exceeded 50 dB in the better ear and/or 70 dB in the poorer 
ear, allowance being made for an audiometer calibration at that time, 
which was different from the current BS EN ISO 389: 1997.

(b) ‘Factors which influence the degree of hearing loss’: (1) exposure 
duration, (2) shift duration, (3) sound level, (4) age of subject, (5) consti-
tutional factors (re ‘susceptibility’), (6) character of the noise – continuous 
or intermittent, (7) use of HPDs, (8) reverberation, (9) previous aural 
disease, (10) noise spectrum (at pp. 430–2).

(c) Critical sound level: ‘It is likely that only loud sounds cause damage 
to the ear’ (p 430).


High levels of social noise in Wales. Anecdotal account: she ‘would advise 
the last speaker to go into a certain café in Merthyr Tydfil in the middle of 
the morning and hear the noise there!’

PEYSER A (1911) Die gewerblichen Erkrankungen und Verletzungen des Gehörs bei den 
Industriearbeitern, mit besonderer Berücksichtigung der Schädigungen durch Betriebslärm 
(Ihre Stellung innerhalb des Arbeiterschutzes und der Arbeiterversicherung, sowie die 

There was already considerable knowledge, in 1911, at least in Germany, 
of occupational noise-induced hearing loss: a review, in the German 
language, of knowledge of the disorder.

PHANEUF R, HETU R, HANLEY JA (1985) A Bayesian approach for predicting judged 

A study based upon 965 foundry workers in Québec. (a) The study used 
statistical methods in an attempt to produced more scientifically based 
compensation schemes. To fix the ‘low fence’ these research workers said 
that they considered what frequency combinations to use, what weight-
ings should be applied to each of these selected frequencies, and how to 
allow for differences in hearing acuity between the two ears:

A method of determining the cutoff point (the ‘low fence’) for an administrative 
decision to award compensation is proposed. To construct the predictive system a

159 The occupational diseases and injuries of hearing in industrial workers with partic-
ular regard to impairments due to factory noise (their status under occupational safety 
and compensation, as well as the difficulties in their differential diagnosis).
Bayesian approach and discriminant analysis were employed. Judged hearing disability was used as the criterion with audiometric scores as the determining variables. The common law doctrine of the balance of probability was used as the criterion, namely the 50th centile, on which to propose a cutoff point. The highest precision in predicting judged hearing disability was obtained with an average audiometric score at 1,000, 2,000, 3,000, 4,000 Hz in the worse ear. Assuming that judged hearing disability is a valid predictor of handicap, the cutoff point based upon the balance of probability (50th centile) was obtained at 25 dB. The study also confirmed results from previous studies: (1) hearing sensitivity in frequencies higher than 2,000 Hz is required to predict hearing disability and handicap, (2) judged hearing disability is better correlated with hearing sensitivity in the worse ear (but since occupational noise damage affects the two ears equally the poorer ear is likely to be poorer because it has been affected by factors other than noise), and (3) the audiometric cutoff point for a medicolegal definition of impairment should be lower than what certain technical groups have proposed in the past.’ (authors’ abstract)

Predictions using the four frequency (0.5, 1, 2 and 4 kHz) average were not reported. The criterion for ‘judged hearing disability’ was an affirmative answer to the question Avez-vous l’impression d’entendre moins bien que la moyenne des gens? (Do you have the feeling that you hear less well than the average person?)

(b) It might well be asserted that the answer to the question posed to each worker points to the minimum shift in his own hearing threshold level that he can detect and not to the ‘threshold of disability’, but to make this knowledge meaningful one needs to know the hearing threshold levels of the ‘average person’ that the worker had in mind.

(c) The proportion of foundry workers who consider that their hearing is normal. Despite exposure to high noise levels, the majority (65%) considered that their hearing was no worse than that of the average person.

(d) Individual differences. At least 40 men whose average thresholds were equivalent to, or better than, 0 dB (HTL) considered that their hearing was poorer than that of the average person. At the other extreme, there was one man with an average hearing threshold level in excess of 35 dB who considered that his hearing was not poorer than that of the average person.


Reduction of sound and light tolerance in headache-prone individuals.

Impaired frequency resolution might be responsible for complaints of hearing difficulties in noise-exposed workers with normal audiograms (not confirmed by the Medical Research Council’s Institute of Hearing Research).


Notch frequency for occupational noise-induced hearing loss. Békésy audiometry showed the average frequency to be 4.481 kHz in people with permanent noise-induced hearing loss.


The extent of right/left differences in hearing threshold levels in noise-exposed and non-noise exposed populations. For the adult male general population the average left–right difference is about 4 dB at 4 kHz, falling off on either side of that frequency to an average difference of about 1 dB at 8 kHz and 0 dB at 1 kHz; the values appear to be little different for a male occupationally noise exposed population. Occupational noise exposure would therefore appear not to be a factor influencing hearing asymmetry.


Sweep frequency methods are more sensitive than fixed frequency methods for detecting notches on the threshold of hearing that provide the first evidence for occupational noise damage to hearing.


There is a limitless number of equations/formulae that could explain the threshold of hearing in terms of factors influencing it. Poincaré gives his famous mathematical proof showing that if one mechanical explanation for a phenomenon can be given, an infinity of others can also be constructed. This can be extended to scientific explanations in general (pp. ix–xiv).


(a) Importance of genes in ageing processes: ‘Inactivation of the p53 gene in a large proportion of cancers . . . Expression of the p53 gene induces either a stable growth arrest or programmed cell death’. (b) Relevance of this to noise damage to hearing. Although it might be argued that chronic noise damage to hearing – occupational noise-induced hearing loss –
accentuates the ageing process in the part of the cochlea that is ‘tuned’ to 4 kHz, it is difficult to see how acute noise damage – acoustic trauma and otic blast injury – would work through this process.

(a) The way in which scientific knowledge progresses – essentially by questioning one or more item of currently accepted knowledge (conjectures) and then implementing one or other experiment that might confirm or refute the conjecture (refutations). ‘For the simple truth is that truth is hard to come by, and that once found it may easily be lost again’ (at p. 8). (b) Dismissal of the value of clinical experience per se:

The Freudian analysts emphasised that their theories were constantly verified by their 'clinical observations'. As for Adler, I was much impressed by a personal experience. Once, in 1919, I reported to him a case which to me did not seem particularly Adlerian, but which he found no difficulty in analysing in terms of his theory of inferiority feelings, although he had not even seen the child. Slightly shocked, I asked him how he could be so sure. 'Because of my thousandfold experience', he replied; whereupon I could not help saying: 'And with this new case, I suppose, your experience has become a thousand-and-one-fold' (at p. 35).


(a) Descriptions of characteristics of noise:

The wide variety of descriptions of the characteristics of the noise stimuli highlighted the large number of subjective descriptors for the perceived character of a noise resulting from a physical feature. It appears that a noise can be judged by different features by different listeners [p. 59] . . . In conclusion, this work . . . has introduced a fundamentally new approach to noise assessment based on the acoustic features contained in the noise. (p. 62)

(b) Complaints generating complaints:

There is a strong possibility of hysteresis in the case of noise sources newly introduced into a community, in that they might have to be reduced to a greater extent once complaints have been generated, than would have been the case if the situation had never been allowed to develop to the complaint stage. (at p. 18)

The need to quieten the 0.410" calibre shotgun and the possibility now of doing so:
For people who enjoy rough shooting with a shotgun, but would like to avoid the anti-social noise the guns can produce, the answer is close at hand. The Saddlery and Gunroom . . . can now supply silenced versions of 0.410” . . . single barrelled shotguns . . . The real proof of the pudding was when my colleague and I returned to the farm house to be questioned by the owner, who wondered if we’d had a wasted journey, because he had not heard any shots!


(a) Explaining the need to distinguish between dB and dB(A) and the need to know how the sound energy is divided between the various frequency bands in order to convert sound measurements in dB to levels in dB(A) (pp. 22–4). (b) Typical peak sound pressures for various weapons, for example 160 dB at the firer’s ear for the 7.62 mm rifle and 188 dB for the 84 mm medium anti-armour weapon and the same for the medium mortar (crew positions) (at p. 62). (c) The source of sound hazards:

It is worth noting that the greater risk to hearing comes from a soldier’s own weapons rather than the efforts of the opposition. The greatest risk of all, at least during normal peacetime training, comes not from a weapon but from a simple training device, the thunderflash (peak pressure 200 dB SPL). It is quite common, despite regulations to the contrary, for these devices to be thrown or dropped into slit trenches or vehicles. One thunderflash can easily cause a hearing loss incompatible with further military service. (at p. 62)

(d) Sound levels in tracked military vehicles. The example given on p. 91 is 115 dB(A), reduced to 102 dB(A) with hearing protection.

(e) The effect of combining various hearing protectors:

Finally, the use of ear plugs at the same time as an ear muff or headset gives only a slight improvement compared with the use of either by itself. Use of double hearing protection is only indicated for exceptionally noisy situations. Even then only highly motivated specialist personnel are likely to use it effectively. (at p. 90)


(a) The need for experts to provide a list of the references that will support their evidence:

Necessarily, evidence given by opinion witnesses at trial on questions of liability and causation has greater strength when supported not simply by the word of the expert (however eminent) but also by reference to the standard textbooks and papers on the subject and by any change in the view of the profession wrought by fresh research and/or changing attitudes. The more support that an expert can adduce in this way to give perspective to written or oral evidence used at trial, the more credible will be that evidence. (para. 13.67)
(b) The need to allow time for this to be done and for all the experts involved to have had adequate time to consider the references: ‘Clearly, so that neither party is caught by surprise it is desirable to prepare this evidence sufficiently in advance, so as to enable both sets of experts to consider the respective lists of medical literature evidence to be relied upon and try to anticipate the opposing parties’ evidence in this respect’ (para. 13.68).

(c) The need for experts to refuse to change their reports at the behest of instructing solicitors: the authors cite Lord Denning in Kelly v London Transport Executive [1982] All ER 842 at 851, CA: ‘They (solicitors) must not ask a medical expert to change his report, at their own instance, so as to favour their . . . client or conceal anything that may be against him’ (para. 9.8).


(a) The importance of the single case report and its contribution to expanding medical knowledge (by integrating the new knowledge into clinical medicine with the help of 34 references). (b) An illustration of how doctors go about making a diagnosis: there were no equations or formulae available to ‘predict’ either the existence of such a neurootological gnathostomiatic syndrome or that the patient ought to have such a diagnosis assigned to him. The diagnosis was approached by considering not only what symptoms and both clinical and special signs were present, but also those that were not, as well as having due regard to the time courses and relative severity of such symptoms and signs, but the definitive diagnosis was not made until the worm was extruded from the ear after its wanderings within the skull. (c) How doctors regard such single case reports: just as the clinicians who reported this case considered and discussed other case reports that might have had a bearing on their diagnosis, so clinicians confronted with an otoneurological problem subsequent to 1975 would take into account this case report. The exercise is one of pattern recognition, and such a task does not require that, for any subsequent diagnosis of neurootological gnathostomiatic syndrome, other patients should exhibit exactly the same symptoms and signs with the same time courses. Thus a neurologist in ‘Burma’, where the *G. spingerum* is also to be found, would now have this diagnosis in mind when confronted with a patient having a one-sided facial nerve paralysis that had been preceded by an acute episode of headache and vertigo – weeks before any parasite emerged to shout the diagnosis.

What subjective ratings are being made? In retrospect, almost certainly the subjective magnitude of the hearing threshold level – neither disability nor handicap.


(a) A formula relating perforation size to air conduction hearing threshold levels. (b) Clinico-pathological implications of dismissing 15 dB air–bone gaps. Having regard to the fact that air–bone gaps would be less than these air conduction hearing threshold levels, such recommendations would be dismissing perforations of sizes of one to two millimetres in diameter, a size that would be clearly visible and would be indicative of middle ear abnormality.


With Békésy audiometry it is possible to obtain clinically useful information from 98% of all subjects with a mental age equal to or greater than seven years.


There is a need for caution in interpreting Békésy audiograms in terms of Jerger’s classification.


(a) Normality and a ‘low fence’: ‘our audiometric criterion of normality (20 dB hearing level in the 500–6000 Hz range)’ (at p. 39). (b) Clinical experience of the development of noise tolerance in people with hazardous occupational noise exposure: ‘in clinical work, we had observed unexpectedly high levels of ULL in a number of workers from noisy industries’ (at p. 39). (c) Laboratory finding of greater noise tolerance in noise-exposed individuals (even when the hearing is within the normal range): ‘the experimental data do give a measure of support to our clinical experience of finding excessively high LDL values in noise-exposed persons’ (at p. 42).


The effect of ageing on otoacoustic emissions. Deterioration with age is accounted for by deterioration in hearing threshold levels with age.

The ability of subjects to estimate the weights of objects or lengths of lines with a given bias when rewarded for doing so.


The effect of leisure shooting on left/right asymmetry. At 4 kHz in workers exposed to an $L_{eq}$ of 71–84 dB(A) and who engage in leisure shooting but have never worn hearing protectors is related to the total number of shots fired, a difference of 18 dB being produced by 2000 to 16 000 shots.


Greater hearing loss in workers who developed VWF.

QUETELET A (1835) Essai de physique sociale.

Origin of applying the bell-shaped probability curve of Laplace and Gauss to the distribution of human data after demonstrating that the curve described the heights of French army conscripts and the chest girths of Scottish soldiers. From this Quételet developed doctrine of l’homme moyen, in which average man appears as nature’s ideal, and deviations towards the good as well as towards the bad appear as nature’s mistakes of different degree. This doctrine conflicts with medical concepts of (a) a range of normal values, and (b) ‘nature’s mistakes’ differ both quantitatively (‘of different degree’) and qualitatively.


Ageing being due to a fundamental biological process, apoptosis. This is distinct from the mechanisms underlying noise damage.


‘The rare Ménière’s Disease’.160 In this small textbook on ENT diseases for medical students and ‘newly-qualified practitioners’, not only is Ménière’s disease included but over 100 lines of the text are devoted to it in compar-

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ison with the three lines devoted to occupational (both civil and military) noise damage to the hearing.


What to take as threshold. It is suggested that this is at or near to the midpoint of the up-and-down excursions of the tracked threshold (subsequently referred to as the cursive threshold).


Retrocochlear lesions are indicated by the drift of tracked fixed frequency threshold for a steady state (continuous) test tone. The case of a tumour of the nerve of hearing where recorded threshold shifted 30 dB within 2 minutes.


It is now clearer than ever that mind and body can no longer be regarded, or dealt with, as separate despite our bondage to Cartesian dualism.


Limitations of predicting annoyance from acoustic features of relevant vehicles. Author concluded that ‘Current field and laboratory research does not appear to firmly establish a unique trading relation between aircraft noise level and number of events. Furthermore, the formulation of a dose–response relation for the prediction of annoyance from transportation noise of all kinds does not yet seem justifiable’.


(a) The threshold measured by continuous fixed frequency self-recording audiometry is about 5 dB more acute than indicated by BS 2497: 1954. The use of TDH-39 earphones with MX-41/AR cushions. NBS 9A coupler calibration. (b) It expresses desiderata for all scientific/technical studies in precise specification of the equipment (also included serial numbers of the instruments).

An explanation for subjects with nonorganic hearing loss giving Békésy audiometric traces that show better thresholds for continuous (sustained) than for intermittent (pulsed) test tones. Normally, higher sound pressure levels are required for pulsed than sustained test tones to achieve equal loudness on the Békésy audiometer.


The problems of pure-tone audiometry can be conveniently grouped into three distinct phases. The first and most fundamental of these is the determination of the absolute threshold of hearing for normal listeners. The second is the transfer of this information to the dials of practical audiometers, which we refer to as the realization of the audiometric zero. Finally there is the actual technique of hearing loss measurement, which is principally though not exclusively to be thought of in terms of clinical application . . . The importance of an internationally agreed set of standard values for the normal threshold of hearing, as a step towards interchangeability of clinical information, is widely recognised, and the task of formulating such a standard has been undertaken by the Acoustics Committee of the International Organization for Standardization (ISO). (Introduction)


Medical Research Council/National Physical Laboratory Survey of noise and hearing in industry.


Noise pollution level as a unifying concept for quantifying environmental noise.


Shows that a single index, the noise pollution level, can accommodate survey results of aircraft and motor vehicles. The index is based upon two terms, one representing the equivalent continuous sound level on the energy basis, and the other representing the augmentation of annoyance when fluctuations of the noise level occur.


(a) Previous underestimation of influence of non-occupational noise:
in addition to the noise, numerous intervening factors also operate, all of which
tend to obscure the principal relationships . . . General acoustic wear and tear on the
organs of the internal ear, or socioacusis, in greater or lesser degree is a reality of
modern life . . . so that neglect of non-occupational noise is tantamount to a straight-
forward underestimation of the accumulated noise dose. Here, then at the simplest
level of consideration is the possibility of quantitative error, perhaps significant, at
the lower end of the occupational noise range. (at p. 383)

(b) The pattern of noise damage to hearing:

a dip in the average audiogram at 4 kHz is always the first feature to appear (we may
nevertheless recognize individual deviations with dips at 3 or 6 kHz). This dip at first
deepens and later flattens off due to the decelerating function; thereafter the
hearing levels at other frequencies begin to catch up, beginning with 6 kHz because
that is rising fastest with age. The dip then smears out or turns into a shape increas-
ingly progressively with frequency, distinguishable from that of non-exposed
persons only by the increased level at lower frequencies. (at p. 390)

ROBINSON DW (1984) Audiometric configurations and repeatability in noise-induced
hearing loss. ISVR Technical Report No. 123. Institute of Sound and Vibration Research,
University of Southampton.

(a) Symmetry of hearing threshold levels in occupational noise-induced
hearing loss: ‘Notch frequency and depth are highly correlated between
right and left ears’ (in Abstract). (b) Reproducibility of measured thresholds:

the mean audiogram level (average HTL across 6 frequencies, i.e. 0.5, 1, 2, 3, 4 and
6 kHz) repeated on average to within ± 3 dB . . . Positive and negative shifts were nearly
equal in frequency of occurrence indicating that the principal cause was a random
process, and this is attributed mainly to subjective uncertainty of the threshold.

The study was based upon an analysis of a selected sample of the
subjects in the MRC/NPL survey of noise and hearing in industry 20 years
previously. Subjects had been tested by Rudmose self-recording audiome-
try. The sample

was restricted to cases where the effects of noise had been sufficient to elevate the
audiogram well out of the range of normal hearing . . . Specifically the following
criteria were applied: (a) a measured HTL of at least 30 dB for at least one frequency
in both ears, and (b) a noise immission level (NIL) of 104 dB(A) or greater.

An NIL of 104 dB (NI) would be achieved by unprotected exposure to
an $L_{eq}$ of 104 dB(A) for one year, 87 dB(A) for 50 years, or for sound levels
between these two levels for corresponding durations between one and fifty years.

(a) There is ‘no way by which the age-related and noise-induced components of hearing loss can be separated for an individual’. (This statement will also apply to separating the various gender and socio-environmental factors from one another and from age-related and noise-induced components.) (b) Provides a quantitative method to look at the pattern of the audiograms, including asymmetry. (c) A 4 kHz notch is not specific to occupational noise damage to hearing. This is not a sensitive test. It errs on the side of not detecting conditions other than occupational noise damage to hearing. It should be remembered, however, that the test was based on the analysis of 63 cases selected from the larger population of the MRC/NPL Survey of Noise and Hearing in Industry. This sample was therefore more than a predominantly occupationally noise-exposed population; it was an exclusively occupationally noise-exposed population. Indeed the selection criteria included the requirement that the worker should have been exposed to a noise immission level of between 104 dB (NI) and 131 dB (NI) so that many plaintiffs would be outside this range. Moreover, as the analysis was based upon data from the MRC/NPL Survey of Noise and Hearing in Industry it was restricted to hearing thresholds determined with self-recording audiometry in the frequency range of 0.5 kHz to 6 kHz.


(a) A new model (based upon a review of ‘the relevant British and international standards and the major scientific studies of the last three decades’, comprising a total of more than 13 000 ears) for the relationship between noise exposure, age and hearing threshold level (the equal-energy hypothesis discarded). (b) Gender differences:

In those studies where comparable noise exposures for males and females have been examined, it is common ground that the effects (of occupational noise) are substantially less in females. The indications are, however, that the observed differences of HTL are also present in non-exposed populations, sufficient to account for the difference in noise-exposed populations without invoking a hypothesis of inherently different noise susceptibilities between the sexes. [at p. 138] . . . the results seem sufficiently clear cut to indicate that there is a real difference, equivalent to several decibels expressed as a noise limit for corresponding standards of hearing conservation, but that the difference has more to do with the hearing loss that is not specifically related to noise than to the part that is. (at p. 140)

(c) If they live long enough people end up with same threshold whether or not they have had any previous hazardous occupational noise
exposure: ‘the HTLs attained at the age of 60 or 65 years in the general population, when compared with those of noise-exposed persons of similar age, left little margin to account for the specific effects of noise’ (p. 32).

(d) The age at which effect of occupational noise is at a maximum: ‘The difference between the exposed and the non-exposed appears to be at its greatest between the ages of 45 and 50 years’ (at p. x).

(e) Disability/handicap:

The commissioning of this study provided the ability to explore . . . the subjective consequences for the hearing ability of those affected. [at p. iii] . . . Impairment means a change for the worse in the structure or function of an organ . . . Impairment, if large enough, gives rise to disability, that is, the loss of ability to perform functions considered normal for human beings . . . The term disability is not altogether appropriate in hearing conservation, however, and the writer prefers ‘inability’ to describe the beginning and lower levels of what is technically termed disability (this word generally conjures up the notion of more severe conditions). The existence of a disability may, in turn, give rise to handicap, the state of being at a social disadvantage with respect to one’s peers . . . hearing conservation necessarily starts from the concept of disability . . . it is concerned with the preservation of intact ability rather than the loss of it. Hence the material concept is the ‘threshold of inability’. Attempts have been made to identify this threshold by numerous experimenters . . . It is hardly surprising that the pure-tone level so identified (the so-called ‘low fence’) varies from experiment to experiment . . . A full treatment of this subject has been given by Robinson, Wilkins, Thyer and Lawes (1984) in the report of an investigation specifically aimed at identifying the threshold of inability and its relation, on the one hand to various audiological impairment measures, and on the other to self-rated handicap (though, again, handicap is perhaps too strong a term to describe people’s hearing difficulties at the just-not-normal level) . . . The resulting value of HTL, average at 1, 2 and 3 kHz, was found to be approximately 30 dB. By coincidence this is the same numerical value as is used in BS5330 to describe the level above which a ‘handicap’ is deemed to exist . . . 50% of the possessors of this level of hearing loss are still just within normal limits of hearing performance for young persons. Much lower ‘fences’ have been canvassed by some authors, based on the level at which a test group shows a barely perceptible difference in performance from one with a smaller HTL. In the writer’s opinion, such estimates are a case of chasing shadows. (at pp. 129–31)

These views are in contrast to those proposed by the authors of the ‘Black Book’.


The concept of simple (linear) additivity (in decibels) of various factors is no longer tenable (what might be termed ‘compression’ occurs).


(a) The derivation of the noise immission level concept: ‘noise-induced hearing loss is expressible in terms of a composite exposure measure (sound immission) which is proportional to the total frequency-weighted sound energy received by the ear over the exposure period’ (Summary). (b) Use of a hyperbolic tangent as the mathematical function relating the two variables ‘is logically preferable in that its limiting behaviour for zero and large immissions is more plausible (than a quadratic function)’ (at p. 6). (c) Statistical relationships in hearing: ‘we do not imply that all persons respond equally to noise: this is very far from the case and is among the chief reasons why quantitative studies of the essential functional relationships in hearing are difficult, tedious and unavoidably statistical in character’ (at p. 1).


(a) Suggesting a new scheme for the assessment of alleged occupational noise-induced hearing loss by extending the simple ‘bottom up’ approach of the ‘Black Book’. This approach involves addition of applicable non-compensable components of threshold shift. Namely:

- conductive hearing loss, together with any contingent sensorineural component;
- other identifiable sensorineural hearing loss;
- natural ageing loss (oto-senescence);
- nosoacusis;
- socioacusis (from non-occupational noise).

... together with an adjustment according to the claimant’s socioeconomic status.

(b) Numerical value of the socioeconomic factor in the Medical Research Council formula (of Lutman and Spencer, 1991): ‘the value, being an average, must imply values both above and below 3 dB, up to 6 dB’ (at p. 51).

(c) Unsuitability of English common law system to resolve real or apparent conflicts in expert evidence in this field: ‘Experience has shown...
that, on occasion, hearing loss compensation claims which come to Court engender conflicts of technical opinion between expert witnesses . . . Resolution of these questions is not helped by the adversarial nature of Court proceedings’ (at p. 45).


The hazardous occupational noise level threshold is 71 dB(A).


Interdiction against using statistical formulae (or tables) for predicting hearing threshold levels:

The results of research . . . have made it possible to predict with considerable confidence the audiometric consequences of long-term exposure to industrial noise. This statement must be qualified by adding that it applies only to the statistical distribution of hearing levels in a noise-exposed population: prediction for the individual remains impossible. (Preface)

Thus there is no approval for using the tables for either diagnosis or prognosis. In contrast, the tables may be used for retrodiction (retrospection).


Notching at 6 kHz is due to an ISO 389 error, but this standardization/calibration problem has since been clarified by the work of Lutman and Qasem (1997).


(a) One method of analysing statistical data to provide numbers for the derivation of ISO 7029 was to look at change in hearing threshold levels with increasing age. (b) Formula derived for predicting the age effect for otologically screened groups (i.e. not individuals) in the form of a power function.

(a) Difference in hearing thresholds measured by manual and pulsed fixed frequency self-recording audiometry:\textsuperscript{161}

Tones were always presented in the order 0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz [at p. 43] . . . The results can be summarized for practical purposes as follows: at 0.25 Hz the difference is nil (accurately 0.2 dB);\textsuperscript{162} at all other frequencies the threshold by $B$\textsuperscript{163} is 3 dB (accurately, 2.8) below the threshold by $M$.\textsuperscript{164} On slightly less direct evidence we believe that it would be equally true to amend this rule to read: zero at the first frequency\textsuperscript{165} [at p. 58] . . . the inter-session effect\textsuperscript{166} which we find to be 1.4 dB over 15 months . . . (at p. 61)

(b) Experimental precision: ‘The equipment was calibrated in accordance with ISO Recommendation R389 – Supplement 1, and was maintained to an accuracy of ± 0.2 dB at each frequency throughout the experiment’ (at p. 44).


‘Low fence’: an experimental study using real-life listening situations. (a) The threshold of what was termed auditory inability (defined by the 2 percentile performance on simulated listening tests) corresponded to a hearing threshold level of 38 dB averaged over 3, 4 and 6 kHz. However this threshold was less well defined than the corresponding inability threshold (30 dB) using the frequencies 1, 2 and 3 kHz. The correlation with the hearing threshold level over the frequency band 3 kHz/6 kHz might therefore well have been secondary to the 1 kHz/3 kHz correlation since the various hearing threshold levels are intercorrelated. (b) It is difficult to see how this fence was ‘erected as an administrative convenience’. (c) Note the correspondence of Institute of Sound and Vibration Research’s fence with that given in evidence of clinicians to Industrial Injuries Advisory Council regarding a 30 dB low fence.


\textsuperscript{161} Rudmose-type audiometry.
\textsuperscript{162} As it is the first frequency tested.
\textsuperscript{163} Fixed frequency self-recording audiometry.
\textsuperscript{164} Manual audiometry.
\textsuperscript{165} That is tested.
\textsuperscript{166} That is, the practice/learning effect from the first to the second audiogram.
Tinnitus is associated with occupational noise-induced hearing loss (based upon an examination of four clinic patients and 44 boilermakers and riveters examined at their place of work).

With regard to subjective noises, 56 per cent. gave a history of this symptom. Barr found it in 34 per cent. of his cases, and I agree with him that it is in the early days of their occupation that men suffer from it. Most of the apprentices said that they had noises after leaving their work at night, and many of the older men, who at first replied in the negative to the question, admitted, when more closely questioned, that in their earlier years they had suffered [but did they actually 'suffer', or did they 'experience', tinnitus?] from such noises. (at p. 102)


Aside from the possibility of evidence being contaminated by deliberate false statements, evidence may be contaminated by other false statements: witnesses have varying degrees of defective memory, including genuine false memories; experimental studies demonstrated that individuals may assert with complete confidence that they remember things that have never happened.


Potentially hazardous noise levels in military helicopters.


(a) Early recognition of the importance of pathology and its relevance to understanding diseases of the inner ear.

The most conclusive solution of these important problems is to be found in post-mortem examinations of those cases which have been carefully observed, as to their aural symptoms during life, but while waiting for the pathologist, the clinicist may contribute his mite toward the desired end. To this end I have carefully collated from the records of my private practice, during the past ten years, those cases of impairment or loss of hearing in which the diagnosis of disease of the internal ear has been made, with the special object of ascertaining what they may teach and how they may be classified. The published records of post-mortem examinations of cases having similar histories, in some few instances have given a warrant for the classification adopted, but, in the main, they will be found to be purely clinical, and lacking, as yet, that positive demonstration which the dead-house alone can furnish. (at p. 377)

(b) Recognition that one cannot take a too-restricted view in assessing a patient. ‘Thus diseases overlap each other, and a narrow, special view becomes impossible to the true scientific observer’ (at p. 377).
A study of a small sample of boilermakers gave results (pp. 382–3) that were consistent with those reported subsequently by Barr – tinnitus occurs early, if at all, in the course of hazardous occupational noise exposure.

ROOSA DB Stj (1887) Remarks upon the diagnosis of chronic lesions of the labyrinth or acoustic nerve with illustrative cases. Transactions of the American Otological Society 4: 34–48.

(a) The picture of clinical otological practice at that time, including perhaps the first case report of tinnitus arising from psychological factors:

Case V . . . The patient is a married physician . . . somewhat overworked and lately very anxious and nervous, who has suffered for the past seven weeks or more with a sense of fullness in his ears and tinnitus . . . There is no pain in the ears and he is not dizzy . . . He was very nervous and anxious. He did not sleep well and was scarcely able to attend to his practice . . . The foregoing cases could easily be multiplied in my experience. I have simply gone over my case book for the past six months . . . Such patients very often exhibit symptoms of nervous exhaustion. (at p. 42)

(b) It is appreciated that gunfire could damage the hearing. A case of acoustic trauma is cited:

When the watch and voice are both heard badly, there is indeed cause for anxiety, but many people go through life with some lesion of the nerve which causes them to hear a watch and certain other tones badly, who hear conversation fairly well until their lives are ended. I have in mind a conspicuous example of this kind in a lawyer of middle life, whose acoustic nerves were injured by cannonading during the Civil war. (at p. 42)

(c) An illustration of the fallacy of post hoc ergo propter hoc: (i) ‘The late Dr Edward T Eley and myself reported a case where a kiss upon the ear ultimately caused a lesion of the labyrinth, and a similar case has been reported in Austria’ (at p. 38). (ii) ‘Case VIII . . . For 12 years this patient has been troubled more or less with impairment of hearing and occasional dizziness. Tinnitus he has suffered from constantly . . . We advised . . . that the mastoid process of each side be kept sore by a blister. This treatment was continued almost constantly for more than 90 days. He seemed to be very much improved. He had no vertigo or tinnitus’ (at p. 41).


The effect of tracking direction. Sweep frequency tracings in which continuous and pulsed test tones were each tracked in an ascending mode from 100 Hz to 10 kHz and in a descending mode from 10 kHz to 100 Hz.
showed no effect on pulsed test tones but a downward sweep for continuous test tones accentuated separation between the continuous and pulsed tracings.


Importance of the Interview: ‘the case history is the first test’ (at p. 60).


A questionnaire study showing a correlation between the presence of tinnitus and the duration of occupational noise exposure in older men. Such was not the case for women. However, the ‘presence of tinnitus was related to hearing loss per se and not exclusively to exposure to noise’. Moreover, the authors were careful to point out that they were not dealing with ‘annoying tinnitus’. Indeed the proportion of Swedish 70 year olds who responded to the question ‘do you hear buzzing sounds?’ (27% to 34%) was comparable to the value (37%) for Scottish 65/74 year olds who were asked a similar question (Hinchcliffe, 1961).


Noise-induced hearing loss eventually disappeared within the age-deteriorating threshold:

The participants of the longitudinal study were studied at 70, 75, and 79 years of age. Seventy years old men exposed to occupational noise had 10 to 15 dB poorer hearing in the high frequency range than nonexposed men. The difference in hearing acuity decreased with increasing age. The differences between exposed and nonexposed older persons were no longer significant at age 79. In women there were no differences in hearing sensitivity between those exposed to noise and those not exposed to noise. Men not exposed to noise had 10 to 15 dB poorer hearing at 4 kHz compared with women of the same age also not exposed to noise. (Abstract).


(a) Audiometric pattern of noise damage to hearing and interaction with age:

This review is a compilation of 11 investigations by different authors regarding the progression of hearing deterioration during severe long-term exposure to noise in mines, shipyards, forges, weaving mills, other factories and industries and from field
artillery and hunting. With one exception, the reports concern conditions at times when ear protection was virtually unknown or only seldom used. (at p. 13)

hearing deterioration in the studies begins in the frequency range 4 to 6 kHz . . . after long-lasting noise exposure for 30 to 40 years, the investigations show similar results in the high frequency range from 3 to 8 kHz: the total median hearing loss has generally increased to about the same level of 60 to 70 dB in spite of the great diversity in the character of the noise and the environmental situations . . . In several investigations it has been seen that the increase in the total median hearing loss, despite continued work in the impairing noise, is relatively small in the range 2 to 8 kHz at ages around 50 years or more, even smaller than the median effect of normal ageing in this frequency range. When the effects of noise and ageing are considered in more detail, it is obvious that at younger ages the total hearing loss is by far dominated by the action of the noise. With increasing age, however, both the effects fuse more and more, and at ages over 40 to 45 years . . . it is impossible to distinguish between the effect of the noise and that of ageing in the audiogram, and the ad hoc concept that the noise component and the component of normal ageing act purely additively is no more valid . . . the reported data are only medians or means for the groups in question, which means that about half the subjects showed poorer threshold values than the medians or means discussed in the present review. The often extreme spread in the threshold values in the different groups involves partly very high hearing loss levels in the individual case and thus a very disabling hearing condition in such cases. On the other hand the investigations include also quite a number of subjects whose hearing loss was considerably lower than the median or mean values presented in the articles. In these cases the state of hearing has probably still remained fairly satisfactory in conversational situations in spite of the long-lasting noise exposure at their places of work. (at p. 36)

(b) The current position world-wide:

Finally, it may be repeated that the situation regarding the hearing loss development from occupational noise as depicted in this review generally no longer exists today in most industrialized countries, but in many developing countries hearing protection programmes have not been initiated and hearing damage due to noise exposure is still a very serious problem. (at pp. 36–7)


Noise hazards to motorcyclists.


Importance of syndrome identification: ‘Accurate syndrome identification will decrease the uncertainty for those who have been told that a genetic disease “could not be ruled out”.’

Influence of circulation on hearing: a group of elderly patients with ‘appreciable cardiovascular disturbances’ have significantly poorer hearing threshold levels than a comparable group with no evidence for cardiovascular disease.


Description of the Rudmose audiometer, which is used in many hearing-conservation programmes.


Distinguishes the various types of injury to the ear that can be caused by noise.


There has been an increase in the prevalence of depression over the years.


(a) Demonstration of link between otoacoustic emission behaviour and Békésy audiometric results:

Contralateral acoustic stimulation has the effect of reducing the amplitude and shifting the phase of click-evoked OAEs (the Collet effect). This effect is thought to be mediated via the medial efferent system and, therefore, the presence of this effect could be used to test the integrity of the neural pathway from one cochlea to the other. (at p. 391)

In a patient with a tumour pressing on the right vestibulocochlear nerve

there was no inhibition of left sided emissions when BBN (broad band noise) was applied to the right [ear] . . . the performance of the right vestibulocochlear nerve had been affected sufficiently to cause marked abnormal auditory adaptation but not enough to significantly raise pure tone audiomigic thresholds. (at p. 396)

(b) A technique required for clinical application: ‘a technique for demonstrating the influence of contralateral acoustic stimulation on click-evoked OAEs was designed to overcome fluctuations in patient and environmental noise’ (at p. 391).

An approach to the assessment of an individual case: ‘If there is a fault in us bred of familiarity it is, I believe, the old fault of omitting to probe sufficiently deeply into causes’.


The presence of 4 kHz notches in excess of 20 dB in the audiograms of 2.3% of children. Prevalence and severity increased with age (at p. 50).


The high prevalence of tinnitus in boilermakers. Prevalence increases with increasing duration of employment, but so does vertigo in his group. There is no mention of how intrusive either of these symptoms were.


Theoretical and methodological bases for evidence-based medicine.


The application of principles of evidence-based medicine (EBM) to patient care.


The multifaceted nature of evidence-based medicine: (a) patient management decisions are to be based upon patient-, population- and laboratory-based evidence; (b) the problem determines the nature of the evidence that is required; (c) it is necessary to obtain, collate, and integrate information from many sources: biostatistical, epidemiological, pathophysiological, and personal; (d) the application of integrated information to patient care.


Protective effect of apoptosis (the ageing process) on extrinsic damage to tissues (relevant to question of how noise-damage and presbyacusis might interact).

How a clinician makes a diagnosis. Fundamentally, clinical prediction is always actuarial when the word is understood in its broadest sense.


The use of the question: ‘At any time have you had a job where it was so noisy that you had to raise your voice to be heard?’ as criterion for a potentially hazardous noise environment.


Hearing damage incurred by (predominantly) jackhammer (pneumatic drill) operators. (a) Despite noise levels of 93 dB(A) to 117.6 dB(A), with peak levels of 118 dB(A), the noise had little effect on the hearing for frequencies below 3 kHz. (b) Early damage: ‘mean thresholds after 10 to 19 years of exposure do not differ from those with five to nine years of exposure’ (at p. 625).


The many causes of audiometric notching at 4 kHz.

Such dips may be produced by numerous factors other than noise, including viral infections, skull trauma, hereditary hearing loss, ototoxic drugs, acoustic neuroma, idiopathic sudden hearing loss, inner-ear membrane breaks, barotrauma, neurologic disease, systemic toxicity and other causes. (at p. 24)


(a) Requirements in the medicolegal assessment of occupational noise induced hearing loss.

When rendering a judgment, it is no longer acceptable to conclude that a person has occupational hearing loss simply because he works in a noisy plant. The differential diagnosis is lengthy, and it must be established on the basis of positive evidence. Not only are there potentially staggering sums of money involved (leading to a natural increase in spurious claims of noise-induced hearing loss), but there are also many serious causes of deafness that may mimic occupational hearing loss. It is our medical (and medico-legal) obligation to ferret them out. In order to establish a diagnosis of occupational hearing loss, one must have at least a history of adequate exposure to noise levels sufficient to explain the hearing loss, a complete audiogram (air conduction, bone conduction, and discrimination) consistent with noise-induced hearing loss, stability of the hearing level after the subject is removed from noise exposure, absence of other causes of hearing loss, and other data. The differential diagnosis
must include presbyacusis, noise-induced hearing loss from recreational (not occupational) causes, diabetes, syphilis, ototoxicity, head trauma, malingering, acoustic neuroma, hereditary hearing loss, and many other causes. Even the typical ‘4000-Hz dip’ audiogram that shows maximum hearing loss between 3000 and 4000 Hz can be caused by many conditions other than noise. (at p. 4)

(b) No mention of the existence of an acute form of occupational noise-induced hearing loss, although the Preface (at p. xii) states

An effort has been made to include practically all known causes of hearing impairment . . . Industrial physicians will find this comprehensive review particularly helpful in deciding whether hearing loss among personnel is related to industrial noise, head injury, or nonoccupational causes . . .

and 16 pages are devoted to the topic of ‘sudden sensorineural hearing loss’: ‘[t]he cause of most of these cases is unknown, but viral and vascular etiologies are believed to be important’.


(a) The authors adopt a ‘relatively stringent definition’ for normal hearing of pure-tone thresholds which are not in excess of 20 dB at each frequency up to and including 4 kHz in each ear. (b) This work was unable to confirm Pick and Evans’ claim that impaired frequency resolution might be responsible for complaints of hearing difficulties in noise-exposed workers with normal audiograms.


There are at least three physiological mechanisms which mediate the damaging effects of noise on the inner ear: mechanical, biochemical and circulatory.


Scope of sensory psychology (psychophysics).

How dim is the dimmest star you can see? How much louder is the roar of a passing jet than the rumble of a trailer truck? These two kinds of questions represent nearly the whole content area of sensory psychology, for the first question concerns thresholds and the second question concerns sensory magnitudes. (at p. 3)

167 A synonym for auditory disability with normal hearing.

‘What do psychoacousticians and audiologists measure? We say hearing. In fact, in laboratory and clinic, it is listening that we most often measure.’


A psychophysical function (in this case a loudness function) shows as a continuous curve without any evidence of a point of inflexion, or ‘knee point’. Any evidence for particular, specific levels, for example a level of most comfortable loudness, or the threshold of uncomfortable loudness, will depend on implementing different experimental procedures.


Validity of noise immission level concept: tested on data for 649 hazardous occupational noise exposed workers. Analyses failed to endorse the concept.


Selection of controls, so necessary to determining the validity of epidemiological studies.


Neither impaired frequency selectivity nor impaired temporal resolution is specific for any one type of inner ear disorder.


(a) Structural basis for occupational noise-induced hearing loss (at p. 306). (b) Identity of hearing loss in some plaintiffs with what American otologists would diagnose, on clinical and pathological grounds, as ‘sensory presbycusis’ (at p. 390). (c) Audiometric patterns for Ménière’s disease (Figure 12.2 at p. 454). (d) Existence of a condition termed cochlear hydrops: ‘Atypical forms of Ménière’s disease are . . . cochlear Ménière’s disease in which only the characteristic auditory symptoms are present without vertiginous episodes’ (at p. 454). (e) The mechanism by which infections of the middle ear can affect the inner ear: ‘The round window membrane . . . is of importance as a site by which toxic substances [bacterial exotoxins, chemical solutions] may enter the inner ear’ (at p. 60).
SCHUKNECHT HF, NEFF WD, PERLMAN HB (1951) An experimental study of auditory
damage following blows to the head. Annals of Otology, Rhinology and Laryngology 60:
273–89.

Head injury producing an audiometric pattern indistinguishable from
noise damage to the hearing. The explanation is that a blow to the head
produces a disturbance to the inner-ear fluids, which is similar to that
produced by intense sound stimulation.

SHAPIRO SL (1959) Deafness following short-term exposure to industrial noise. Annals of

‘Industrial sudden deafness’. Six case histories of workers exposed to
intense noise of pneumatic tools or heavy hammering developing
endolymphatic hydropic type hearing losses but all within 8½ days of such
exposure.

SHAW EAG (1979) Hearing protector attenuation: a perspective view. Applied Acoustics 12:
139–57.

The theoretical basis of how hearing protective devices work.

Scott-Brown’s Otolaryngology. 5th edn. Volume 3. Otology. London: Butterworth,
chapter 10.

Audiometric assessment in chronic suppurative otitis media. ‘An accurate
pure tone audiogram with appropriate masking for air and bone conduc-
tion is carried out at the first visit and at intervals to determine, in partic-
ular, the level of cochlear reserve . . . A speech audiogram with masking is
advisable’ (at p. 222).

SHIPTON MS (1979) Tables Relating Pure-Tone Audiometric Threshold to Age. NPL
Acoustics Report Ac 94. Teddington: National Physical Laboratory.

A convenient tabulated form for formulae in ISO 7029.

Data from the literature on presbyacusis has [sic] been critically evaluated by
Robinson and Sutton (1978), who derived a formula for generating the age effect of
otologically screened groups of males and females for pure-tone frequencies from
0.125 to 12 kHz. This report presents their findings in tabular form. (Summary
attached to ISO 389.)


(a) Tinnitus and occupational noise-induced hearing loss: (i) after the
exclusion of 56 workers ‘whose hearing was impaired owing to earlier
aural diseases and injuries unconnected with the occupation’, 60% of the remaining 303 workers (95% men) reported a complaint of ‘buzzing in the ears’ but no control population was reported. The authors said that ‘the majority of the workers were [sic] more or less exposed to noises’ associated with the recent war (there was the Winter War of 1939/1940 and then, after a short period of peace, the Continuation War of 1941/1944). Moreover, the sampling was anything but random: ‘the examination was arranged on a voluntary basis, those who had noticed a hearing defect being particularly requested to present themselves for examination’.; furthermore, the workers would have been questioned in the Finnish (or Swedish) language; (ii) no mention of tinnitus severity nor of delayed onset tinnitus. (b) No mention of the existence of an acute form of occupational noise-induced hearing loss.


A laboratory demonstration of the development of loudness tolerance (10 dB increases) associated with exposure to high sound levels; the increased tolerance being equivalent to a doubling of the loudness which more likely than not would persist over a quiet period of at least 26 weeks.


Bone conduction thresholds in unilateral conductive hearing losses were not better than the air conduction thresholds in the contralateral ears of 24 patients who had had industrial noise exposure but there are problems in knowing (a) how much to allow for effects (mechanical and other) of the middle ear disorder on bone conduction hearing thresholds, (b) whether or not there had been any occupational noise damage to the ear prior to middle ear disorder taking effect, and (c) to what extent bone conduction thresholds in the ear with no conductive impairment had been affected by noise.


A special case of marked lateral differences in hearing threshold levels due to an essentially monaural high-level noise exposure (of the order of 140 dB(A)). This produces a unilateral aural acoustic trauma. ‘All of the patients (13) described a painful sensation in the ear associated with exposure to the ring. They were immediately aware of a hearing loss and experienced the onset of tinnitus of varying degrees’.

Characteristic X-ray features of the middle and inner ears in the syndrome. Abnormalities of both inner and middle ears in all of seven patients examined, but all had ‘bilateral mixed hearing losses’.


Powerful effect of suggestion in normal people: even blood pressure can be manipulated by suggestion.


The ongoing reassessment of the statistical formulae relating age, gender, socio-economic group and noise exposure is not specific to hearing but applies to other statistical biological formulae.


Difficulties in reconciling mechanisms of the common law system with an evidence-based society.


Retirement and redundancy being associated with considerable psychological stresses, so-called occupationless health.


Socio-economic factor(s) influence levels of health and are becoming increasingly more evident.


Generalizing from results on a sample. ‘Generalising from a sample to a population is an example of inductive reasoning . . . All inferences are the product of human imagination and so it is unlikely that there can be one absolutely correct method of inductive reasoning which would be acceptable to us all’ (at p. 156).

(a) ‘Low fence’ as derived from laboratory tests for the understanding of speech in noisy situations and comparing results with thresholds of hearing for pure tones. ‘The correlation coefficient equals 0.72 . . . Splitting up the data according to HT (2,4)-Intervals of 10 dB, and even of 5 dB, shows that there is no change in SRT up to HT(2,4) = 10 dB. Above 10 dB, the SRT starts to rise.’ This is not surprising if one accepts Stephens’s and Hétu’s thesis that these tests of hearing speech in a noisy background are actually complex tests of auditory function – measures of hearing impairment. They do not conform to their definition of hearing disability. (b) Appreciation of different purposes of ‘low fence’ concepts. ‘Thus, from the point of view of preventive medicine, the target fence that we should strive for is HL(2,4) = 10 dB’ (at p. 340).


Whether one finds a power psychophysical function or a logarithmic psychophysical function depends on what is being scaled and how.


(a) The possibility of experts misinterpreting scientific knowledge and arguments. (b) The need to distinguish between determinism and predictability:

Determinism depends on what Nature does (independently of us), while predictability depends in part on Nature and in part on us. To see this, let us imagine a perfectly predictable phenomenon – a clock, for example – which is, however, in an inaccessible place (say, the top of a mountain). The motion of the clock is unpredictable, for us, because we have no way of knowing its initial state.

168 The obvious but not the best translation of the title of the first (French) book, as this implies that the philosophers whom the authors attack have been engaged in wilful and fraudulent deceptions. This is not the case. Misconceptions or false reasoning are not necessarily deceitful. Thus a better title to the English edition would have been ‘Intellectual Fallacies’, and a more appropriate title for the French edition would have been Les Illusions Intellectuelles. Indeed the only publication where there was a deliberate attempt to deceive was the paper ‘Transgressing the boundaries: toward a transformative hermeneutics of quantum gravity’, which the first author had published in 1996 issue of Social Text (a deliberate hoax to prove his point – in the French language, une mauvaise plaisanterie, the only ‘wicked’ publication in this scenario).
But it would be ridiculous to say that the clock’s motion ceases to be deterministic. (at pp. 131–3)


Application of mathematico-statistical methods to classification, including diagnosis: ‘The book is not merely a textbook, however, and the methods it describes have broad applications . . . pattern recognition . . . and certainly, not least important, medical diagnosis’ (cover).


The deterioration in hearing threshold levels with increasing age. A logarithmic formula fitted the data.


There was no association between psychiatric illness and noise exposure, although there were associations between depressive illness, hypersensitivity to noise and future psychiatric illness.


Definitions of medical terms.


It is standard practice in auditory epidemiology to subtract 2.5 dB from ‘averages’ to take into account audiometer attenuator step size (5 dB).


Aircraft passenger comfort/discomfort is dependent on both noise and vibration levels, which interact with one another.

Possible consequences to hearing that result from disorders of the sound-analysing organ of the inner ear: a review of 37 papers that had appeared over a period of half a century had demonstrated multifarious effects.


The complexity of problems of impairment of hearing.

Before starting a programme of auditory rehabilitation for a hearing-impaired patient, it is imperative that the patient should be thoroughly evaluated. Such an evaluation will be from a diagnostic standpoint, from the standpoint of his auditory performance, his audiovisual function, his manipulative skills and finally of his psychosocial function and difficulties. (at p. 205)


The complexity of hearing disability and of handicap.


Influence of anxiety on loudness tolerance.


The occurrence of specific, localized levels (in this case, the most comfortable loudness level and the threshold of uncomfortable loudness) on a continuum (in this case, the psychophysical function for loudness) that does not exhibit any corresponding points of inflexion.


(a) The need to distinguish between the terms ‘impairment’, ‘disability’ and ‘handicap’ as they are used by the World Health Organization (WHO) (and in the UK) and as they have been used in the USA. In respect of hearing, the WHO considers impairment to be a measure of defective auditory function. Disability is the auditory problem experienced and complained of by the individual. Handicap encompasses the non-auditory consequences (for example, occupational, sociological, psychological, economic) of hearing impairment and hearing disability. (b) The need to recognize that some of the hearing tests that are put forward as tests of hearing disability are actually complex tests of auditory function –
measures of hearing impairment. ‘There is a real continuum of tests ranging from the simple pure-tone signal . . . to sentence recognition in noise’ (at p. 187).


The need to test the speech–hearing ability of Welsh speakers with Welsh speech audiometry. Aside from the obvious factor of knowing the language, there are different response patterns, including absence of voiced/voiceless speech sounds confusions.


The condition in which an individual perceives that he or she has hearing difficulties but the pure tone audiogram is essentially normal. ‘Normal hearing’ is defined as a maximum HTL averaged over 0.25 kHz to 8 kHz of 20 dB in each ear with a maximum HTL at any frequency of 30 dB.


A psychophysical function (in this case a loudness function) shows as a continuous curve without any evidence for a point of inflexion, or ‘knee point’; any evidence for particular, specific levels, for example a level of most comfortable loudness, or the threshold of uncomfortable loudness, will depend on implementing different experimental procedures; numerical modifications to the function may be required to meet the requirements of logic (see Scharf and Stevens, 1959).


A procedure based on octave band analyses of sounds for calculating loudness of sounds; used for method A in BS 4198.


Calculating loudness from noise analyses: a nomogram presented to relate SPL in octave bands to loudness in sones.


The broad scope of the psychophysical power law. For example, it even applies to subjective magnitude estimations of the aesthetic value of drawings and of handwriting as well as of the seriousness of stealing.
various amounts of money, in none of which is there a clear overt physical stimulus measure.


‘What can the clinician do with his facts beyond that which can be done by the mechanical application of an actuarial table or a regression equation?’ The author emphasizes that the clinician may give more weight to one or other factor than is given in an actuarial table. (Or, more commonly, he will take into account one or more factors that are not included in any actuarial table or formula.)


The effect of ageing on otoacoustic emissions. Deterioration with age is accounted for by deterioration in hearing threshold levels with age.


The complex origin of the ‘echo’ within the inner ear.


Relative importance of the various frequencies for monosyllables and for connected discourse.


(a) The association between structural change in ear and audiometric pattern (based upon a histopathological study of ‘17 aged patients who had spontaneous and gradually progressive bilateral sensorineural hearing losses associated with aging’). ‘Our observations show that a certain type of audiometric curve does not necessarily indicate a lesion in a specific cochlear element’ (at p. 169). (b) Abrupt high frequency hearing losses of the noise-damage pattern may occur in the absence of a history of hazardous occupational noise exposure: ‘Case 3. A retired surgeon with a bilateral sensorineural hearing loss at 4000 and 8000 Hz . . . The patient had no known history of exposure to noise’ (at p. 175).


The eventual arrest of the progressive course of the illness. ‘The audiological examinations carried out on the cases described revealed several character-
istic features of hereditary progressive sensorineural deafness. One such finding is that the progression of hearing loss stops spontaneously at a certain level and does not develop to total deafness’ (at p. 681).


‘Industrial sudden deafness’. Six cases, including a 28-year-old driver with a single exposure to 120 dB(A) in a piston engine test house, and a 26-year-old man in his third month of work at manual plate straightening where the noise level was 105 dB(A).


(a) This provides data for an otologically normal, non-occupationally noise-exposed Polish population (at p. 168). (b) Pattern of speech audiometry in occupational noise-induced hearing loss (uncontaminated by non-organic hearing loss):

In cochlear deafness (with the presence of recruitment) an increasing discrimination loss at higher intensities of speech sounds is observed . . . after having passed the intelligibility maximum, the articulation curve bends and even drops (so-called regression curve), which means that the intelligibility will decrease with further increasing intensity . . . Similar pictures are observable in an occupational hearing impairment. The shape of the articulation curve – depending on the extent of the impairment – defines the size of the discrimination loss, which increases as the intensity increases. (at p. 153)

(c) This document stresses the observation that ‘industrial sudden deafness’ appears on a day when the potentially hazardous occupational noise levels are no different to what they have been on previous days (at p. 22). It thus poses the question as to whether or not the noise is causative of the sudden hearing loss.


Depression, stress or anxiety are antecedents to troublesome tinnitus.


Circulatory condition is a factor determining the state of hearing. Hearing impairment is three times more common in people with coronary artery disease than in a comparable group of people.

We consider the Botsford-type method in which the protection offered in a flat noise spectrum is used (with the mean attenuation corrected by 1 or 2 SD) is highly acceptable as the single-number procedure in terms of accuracy and simplicity. This rating is simply subtracted from the $C$-weighted noise level to give the closed-ear $A$-weighted level. Thus if we have a noise whose $C$-value is 109 dB(C), then we can be 95% sure that any protector whose single number rating (as defined above) is 19 dB or greater will protect 80% of wearers to below 90 dB(A) . . . It must be emphasised that a single-number rating based on this method must be used in conjunction with the $C$-weighted, not the $A$-weighted, sound level of the noise. The above method is thus very close to the EPA method except that here we include no ‘safety factor’ correction – the need for this has been eliminated by the choice of the spectrum which gives the single number rating, and by a conservative adjustment of the percentage (84 to 80, and 98 to 97). (pp. 89–90)


Truth being conformity with the facts.


The likelihood that so-called idiopathic (unknown cause) hearing losses are genetic: ‘The most significant finding is the almost complete identification of the pure tone audiogram of the genetic familial group with the “unknown” group’ (at p. 83).


There is considerable variability in the way that doctors reach the same (and correct) diagnosis. ‘Considerable variation in clinicians’ routes to correct diagnosis is shown’ (Summary).


Tinnitus associated with occupational noise-induced hearing loss: ‘A common symptom found in occupational deafness cases is tinnitus which when measured for pitch is found to be at or near the maximum hearing loss. In many cases the symptom arises long after exposure to excessive noise has ceased’ (at p. 104). (This is not surprising because over a third of the Scottish rural population over the age of 65 years will say that they have experienced tinnitus.) The author does not refer to any publication.
to support this statement. Although he had conducted an epidemiological study of jute weavers there is no evidence from the publications (for example, Taylor, Pearson, Mair and Burns, 1965; Taylor, Pearson, Kell and Mair, 1967; and Kell, Pearson, Acton and Taylor, 1971) that he had considered tinnitus specifically. It is also to be noted that, instead of starting his historical introduction with a quotation from his fellow Scot, Barr (as he did in his 1967 paper), he refers to the publications by an American, a Belgian, a German, and an Italian. Barr’s report is in conflict with Taylor’s statement on tinnitus.


(a) The occupational hazard of using hand-held vibratory tools, such as hand–arm vibration syndrome (HAVS), previously known as vibration white finger, a disease with vascular, neural and musculoskeletal components. (b) ‘Involvement of the central autonomic nervous system in either WBV [whole body vibration] or hand–arm vibration generally has not been accepted.’ (c) ‘In view of the possible synergistic effect of noise, an audiogram is advised.’


Drop hammer operators are exposed to sound levels of 108 dB(A).


Absence from the questionnaire used to study jute weavers of questions concerning tinnitus.


(a) Pattern of occupational noise-induced hearing loss (L_{ERB} assessed as 100 ± 1 dB(A): (i) it begins at 4 kHz and progresses with this frequency showing the maximum hearing loss; (ii) audiometric high frequency fall off is steeper than that predicted by the NPL Ac 61 model. (b) There is no mention of tinnitus.


The variability in the degree of occupational noise-induced hearing loss at 4 kHz in drop-forgers.

Proposing a scheme for quantifying hearing disability in claimants which scheme takes into account the threshold at 6 kHz.


Impulsive or impact noise measurement:

An impulsive or impact noise is one in which the sound pressure rises rapidly to some maximum value and then decays, to be followed by a period of (relative) quiet. To define an impulsive sound, three parameters are needed. These are the peak amplitude $A$, the rise time $t_r$ and the decay time $t_d$. For a complete knowledge of the impulsive sound it is also necessary to know the shape of the waveform involved. Where the requirement is to determine the average sound level, an integrating or noise average meter will often be able to provide this information in the form of an $I_{eq}$ value. This is normally sufficient for the assessment of hearing hazard. In certain situations it is necessary to determine this parameter (sometimes called ‘peak hold’ or ‘absolute peak’). However, peak measurements must be treated with caution, since some impulsive sources (for example, small-arms fire) show very short rise times of less than 50 µsec, and in these cases sound-level meters may not accurately determine the peak levels. When a full analysis of a very fast rising impulsive sound is to be made, it is usually necessary to use a microphone feeding an oscilloscope and to photograph the resulting trace or to record it on a digital event recorder, which can then be used to plot out the waveform on a chart recorder. Often the situation of a short rise time occurs with a very high peak pressure and necessitates the use of a small capacitor microphone or a special piezo-electric microphone. Such microphones have both a very short response time to high-speed transients and the ability to respond without distortion to high sound-pressure levels. (pp. 17–18)


(a) Produces statistical data relating quantitative features of noise exposure to audiometric measurements on workers:

The first two studies which succeeded in bringing some sort of order to the problem (of the effect of steady-state broad band noise on hearing) appeared quite close together in 1968. The first was the study by Passchier-Vermeer (1968) in which data collected from various sources on 4600 people were brought together. The second report (Robinson, 1968; Burns and Robinson, 1970) was based on a study of about 1000 persons. The reports of Passchier-Vermeer and of Burns and Robinson represent quite different approaches to the problem, and, although in most areas they are in broad agreement, their methods of data handling and presentation have little in common . . . Passchier-Vermeer’s . . . exposure times range from 10 to 40 years, and noise levels are basically defined in terms of noise rating (NR) numbers . . .
general pattern is that the loss is always greatest at 4000 Hz . . . Burns and Robinson attempted a sophisticated analysis, aiming to bring together in a unified form:

1. the effect of noise levels from 75 to 120 dB(A),
2. the influence of duration from 1 month to 50 years,
3. the distribution of hearing loss from the least to the most sensitive members of the population,
4. the effect of presbycusis, and
5. the difference in hearing loss between the sexes.

One of the most important features was the development of the concept of noise immission level (NIL), the total A-weighted noise energy received by the ear. (at p. 49)

(b) There is a need for a quiet period before testing the hearing of noise exposed workers to exclude noise-induced temporary threshold shift contaminating the measurements: ‘Normal practice in industrial audiology is to allow 15–16 hr between noise exposure and testing’ (at p. 66).

(c) ‘Industrial sudden deafness’:

some evidence from otologists of a . . . situation in which a severe loss of hearing occurs after exposure to . . . a steady state noise of a very high level, often with an impulsive content, or to a repeated impulsive noise . . . but due to the relative infrequency of such cases, and the difficulty of quantifying both exposure and the nature of the damage, the evidence for such cases must be regarded a somewhat speculative. (at p. 48)


Non-occupational noise hazards: ‘It seems likely that the single most widespread noisy “activity” is hand hammering’ (at p. 182). What man, let alone manual worker, has not used a hammer?


(a) This clearly distinguishes the role of the medical consultant from that of the noise consultant and the sequence of their involvement.

The medical evidence is normally provided by an ear, nose, and throat consultant, who examines the plaintiff and provides an opinion as to the extent of any hearing loss and its cause. The diagnosis is initially based on the pure-tone audiogram, which, if a diagnosis of NIHL is to be supported, must show at least a fair resemblance to the classic shape, with a ‘notch’ in the 4–6 kHz region of frequency . . . If the audiogram is typical of noise-induced loss, then the rest of the diagnosis is mainly a process of elimination . . . The evaluation of the audiogram must also
consider the extent to which presbycusis will have contributed to the hearing loss. [Diagnosis is thus ‘mainly a process of elimination’ and precedes the use of any tables or formulae] . . . The task of the noise consultant is to obtain the best possible estimate of the noise exposure experienced by the claimant in the course of his work . . . With the aid of Burns and Robinson’s data it is quite practicable to make a judgement as to whether the measured audiogram is reasonably compatible with the noise exposure history. Other valuable data on the relationship between noise exposure are available in the report by Passchier-Vermeer (1968). (at pp. 847–9)

(b) A ‘low fence’. Two schemes are proposed for assessing handicap (according to the 1980 WHO Manual this would be termed ‘disability’). The first is a ‘scheme for use in litigation arising from claims for noise-induced hearing loss’; the second is from an experimental study. Each has a ‘low fence’ (the latter at 24 dB HTL). It is difficult to see how either of these fences was ‘erected as an administrative convenience’.


(a) Reference thresholds:

Ideally, reference populations should include data from the same general geographic area and the same general socioeconomic levels. This helps to ensure that the reference population is exposed to the same environmental factors and probably engage in the same hobbies and extra-work activities as the industrial population. This will help increase the probability that the only remaining variable between the two populations is on-the-job noise exposure. (at p. 182)

(b) Influence of the meaningful threshold shift criteria that are adopted on the number of employees (workforce more than 900) identified as having significantly deteriorating hearing (defined as a shift of 20 dB or more): nearly half of the shifts occurred at frequencies not included in the OSHA criterion and 72% of shifts occurred at one frequency only, with three frequencies or more being involved in only 4% of the employees (but which shifts were attributable to occupational noise damage is a separate question) (at p. 197).


169 Paradoxically, ‘formula application’ has the least scientific legitimacy when applied to an individual. The value of this approach lies in retrodiction exercises.
Equations of statistical models are not to be regarded as functional (biological) models. Thornton gives an example of a regression equation (p. 46) relating speech audiometric scores to pure-tone hearing threshold levels. A strict interpretation of the equation would mean that the poorer the hearing threshold level at 1 kHz, the better the speech intelligibility. Clearly this is not the case.


An increasing number of factors are being incorporated into explanatory numerical models in the non-physical sciences. The use of over twenty equations by the 1969 Nobel Prizewinner to describe Dutch economy. So the half dozen factors that are included in current equations for hearing threshold levels will reflect knowledge so far, as much of the variance has yet to be accounted for.


Establishing a relationship between sensorineural hearing loss and a type of blood disorder that commonly affects Jamaicans: unfortunately no audiograms are presented but the authors state:

hearing loss was of slow onset . . . in no case was the audiogram typical of acoustic trauma . . . high frequencies first affected, followed by low frequencies, and ultimately deterioration at all frequencies . . . possible that a low grade continuous venous thrombotic process . . . affects the cochlea . . . without obvious disturbance of vestibular function . . . there were no neurological signs.


Recognition that more and more syndromes exist: ‘new’ syndromes are being described at a rate of at least one per week. Although some represent variable expressions of previously recognized conditions, many are new syndromes that are being described for the first time.


(a) Importance of pathology

if we carefully survey the history of the rise and progress of Aural, as a distinct branch of Scientific Surgery, one main cause of the disrepute into which it had fallen may be traced to the neglect of the Pathology of the organ of hearing – a neglect that

170 Considered as a medical classic.
doubtless led also to the ignorance which has prevailed as to the structure and function of some of the most important of its parts. (at p. 1)

(b) Importance of correlating symptoms and signs with pathology: ‘By . . . conducting post-mortem inspections of the patients attended by me, I have been able in many cases to compare the symptoms during life, the appearances of the organ, and the history of the case, with the morbid structures found after death’ (at pp. 2–3).


A ‘low fence’. The threshold level at which workers perceive that they have difficulties hearing (a positive response to the question ‘Do you have hearing difficulties?’) corresponds to 48 dB HTL at 4 kHz (by which time the 4 kHz loss would be pulling down the lower frequencies).


For conditions other than hearing. (a) Uncertainty as to the extent to which genetic and/or socioeconomic-environmental factors are important: ‘Medical science is bankrupt of effective treatments for obesity, it confused the public as to whether being overweight is determined by fate or free will’ (at p. 1291). (The National Study of Hearing has shown that both gender and socio-economic factors influence hearing thresholds.) (b) A variety of formulae are developed to ‘explain’ the condition: ‘and it keeps changing the units of measurement . . . body mass index, waist to hip ratio, and waist circumference’ (at p. 1291). (c) Secular changes: ‘At present in Britain the population mean weight is increasing’. (d) The assumption that an average value is the desired value: ‘Ideal body weight is far lower than average’ (subtitle).


The general pattern is that tinnitus becomes less distressing with the passage of time – tolerance develops.


An observation at the Medical Research Council’s Institute of Hearing Research that frequency resolution changes may occur in regions where the threshold of hearing is normal.

Studies at the Institute of Hearing Research of inner ear type hearing losses, attributable either to noise or to other factors, showed that poor frequency resolution was invariably associated with a pure-tone threshold loss. As frequency resolution, pure-tone threshold and ability to understand speech in a noisy background were associated, it was not possible to establish a primary relationship between impaired frequency resolution and speech intelligibility.


The proportion of the population considered to be abnormal depends on criterion for abnormality. ‘According to the WHO classification (1991), 94.3% of the subjects had normal hearing...When the more recent EU definition (1996) was used, 85.3% of the subjects had normal hearing.’


‘Disability’ and ‘handicap’. The Standard Rules set an international standard for policy-making and action:

Both the causes and the consequences of disability vary throughout the world. Those variations are the result of different socio-economic circumstances and of the different provisions that States make for the well being of their citizens. [paragraph 2] . . . The World Health Organization’s International Classification of Impairments, Disabilities, and Handicaps . . . has been extensively used in areas such as rehabilitation, education, statistics, policy, legislation, demography, sociology, economics and anthropology [paragraph 20] . . . As a result of experience gained in the implementation of the World Programme of Action (concerning Disabled Persons)172 and the general discussions that took place during the United Nations Decade of Disabled Persons, there was a deepening knowledge and extension of understanding concerning disability issues and the terminology used. Current terminology recognizes the necessity of addressing both the individual needs (such as rehabilitation and technical aids) and the shortcomings of the society (various obstacles for participation) [paragraph 21] . . . [During the] Year173 and the World Programme of Action . . . for the first time, handicap was defined as a function of the relationship between persons with disabilities and their environment. (paragraph 6)

171 Adopted by UN General Assembly at its 48th session on 20 December 1993 (Resolution 48/96).
172 Adopted by the UN General Assembly by its resolution 37/52 of 3 December 1982.

Hearing thresholds of members of gun clubs were equivalent to having been exposed to 95 dB(A) for 40 years.


Adoption of the equal energy principle in considering the hazardous nature of noise.


The prevalence of tinnitus: tinnitus was classified as ‘severe’ and ‘mild’; the highest prevalence was among women in the age group 75–79 years in which the prevalence of severe tinnitus was 14.4 per 100 adults, and mild tinnitus was 37.3 per 100 adults (at p. 15). The group with lowest prevalence of tinnitus was that of men in the age group 18–24 years: and here severe tinnitus had a prevalence of 1.7 per 100 adults and mild tinnitus of 23.9 per 100 adults.


A list of sound levels relating to various occupations.


Noise levels to which car passengers are exposed: 60 dB(A) to 90 dB(A).


Age-related cell death, which may cause hearing impairment and dysequilibrium, is due to the biological process of apoptosis occurring in the internal ear.


An explanation of how a sensorineural hearing loss might be associated with earpits when the inner ear is generally considered to follow an
entirely different line of development from that of the outer ear. Experimental studies show growth of otic capsule (an inner ear developmental precursor) may be impeded by a layer of cartilage of branchial origin.


Viruses as causes of sudden hearing loss.


Tinnitus is infrequent or not a problem in noise exposed workers. Only one (a boilermaker) of the author’s 254 clinical cases of tinnitus accumulated over a ten-year period could be attributed to occupational noise damage to the hearing. This despite the fact that, in the population which Venters served, ‘there was a definite aural hazard’ (defined as employment in ‘such industries as boilermaking, heavy engineering, sheet metal workers, mining and certain types of factories’) for 9696 people.


Frequency of hyperacusis, particularly in association with tinnitus: ‘The occurrence of hyperacusis is rare. In our Tinnitus Clinic, where more than 4 000 patients have been seen, hyperacusis has been seen only 4 times.’


Sudden hearing loss due to mumps virus not related to clinical severity of condition.


Principles in selecting controls, so necessary to determining the validity of epidemiological studies.


Selection of controls, so necessary to determining the validity of epidemiological studies.

Aside from the effect of a conductive hearing loss, the functional characteristics of the middle ear influence the nature of the cochlear ‘echo’.


Helicopter cabin noise levels averaged 96.7 dB(A) for a Norwegian Air Ambulance BO-105 helicopter during a typical cruising situation.


Correcting statistical models after they have been constructed: ‘just because it is adjusted does not mean it is useful’.


It is difficult to demonstrate any permanent damaging effect of noise on the hearing of aircraft carrier flight deck personnel:

The evidence that noise exposure has produced any permanent hearing loss appears exceedingly flimsy at this point. If one uses the clinical approach, interpreting each individual audiogram in terms of what ‘probably’ caused that particular hearing loss, then there are cases in which one feels quite confident that aircraft noise was the responsible agent. But in the absence of pre-exposure audiograms, one cannot be sure . . . These results are all consistent with the hypothesis that aircraft noise was, at the time of this study, much less dangerous to the hearing of Navy personnel than was gunfire . . . These results emphasise the obvious: one cannot make a valid decision as to the effects of a particular noise environment unless adequate controls are employed. A causal relation between noise and hearing loss cannot be assumed simply on the basis of joint occurrence.


Proposed tests of susceptibility to occupational noise-induced hearing loss: a score or more, with variability in response and difficult to verify;

probably because there are a number of specific susceptibilities as well as a general susceptibility.


The importance of higher frequencies. Advocates for the inclusion of hearing threshold levels at 4 kHz ‘have failed to show that a better prediction of speech perception can be made by including it’.


Acceptability of Kryter’s 1973 paper: (a) ‘The 55-dBA 8-h basic damage-risk criterion . . . is based upon erroneous assumptions and extrapolations from data’. (b) ‘Kryter’s final attempt to establish the reasonableness of his low fence . . . an NIPTS of 15 dB is an NIPTS of 15 dB independent of the reference zero . . . It is not true, therefore, that the CHABA criterion “translates to and is consistent with the average HL of greater than 15 dB at 500, 1000 and 2000 Hz” re ISO proposed in this paper.’


There is no good evidence yet that audiometric measures other than pure-tone thresholds of hearing are more sensitive in detecting noise-induced damage.


Difficulties in assessing the consequences of damages to hearing for the individual, with a critique of a particular US method:

The main problem in attempting to estimate auditory handicap from easily measured indices such as pure-tone sensitivity or intelligibility scores for numbers, words or sentences is that no criterion to establish validity has received wide acceptance. Even though few would disagree with the definition of handicap accepted by the American Medical Association: ‘the disadvantage imposed by an impairment sufficient to affect the individual’s efficiency in the activities of daily living’, this definition is so vague that it is of little practical value. Consequently, all formulae to rate handicap are based on assumptions of a more or less arbitrary nature. A dozen such assumptions are shown to underlie the formula of the American Medical Association/American Academy of Otolaryngology’ [Abstract] . . . No one would question the assertion that a deaf person has a handicap. Yet of all of the areas embraced by the field of audiology,
quantification of degree of auditory handicap and its relation to measurable auditory characteristics is a topic concerning which probably the least agreement exists at international, national or local levels. When such diversity of opinion exists, the main problem is generally a semantic one, namely, a lack of agreement as to the definition of the terms involved, which in turn comes from using a single term to describe several different phenomena. And indeed such is the case here. Dozens of schemes for evaluating handicap exist because dozens of definitions of handicap exist. The issues encountered are seldom scientific in nature but rather social if not downright political, perhaps because the major objective in estimating handicap is for purposes of indemnification. One is hard pressed to think of any reason for wanting to quantify handicap other than determining compensation. True, many people like to have some sort of support for statements such as ‘he has lost 30% of his hearing’, so no doubt continued attempts would have been made to develop a scale of handicap even if nobody could be blamed for causing it and hence could be sued for damages. However, compensation is clearly the underlying driving force in today’s world, and this should be kept constantly in mind in discussing handicap if we are to understand why certain assumptions have been adopted by particular decision-making bodies. Probably because of its links with compensation, therefore, auditory handicap is a most elusive concept, dodging about among and camouflaging itself within its cousins: impairment, abnormality and disability . . . In the interest of completeness, one should also consider the possibility that these failures of perception may not always lead to decreased efficiency; for example, a 16 kHz squeal may be so annoying to those who can hear it that they show less efficient task performance than those who cannot . . . Although it is fashionable to laugh about the naivety of an early system used in California, in which the baseline was provided by the entire auditory area, from 0 dB HL to the pain threshold, and from 20 to 20 000 Hz, with handicap defined as the proportion of that total area that had been lost due to elevated thresholds, it is no more arbitrary than what may be an opposite extreme, the system used in my home state of Minnesota. Due to an unfortunate set of circumstances, percent handicap was accepted, in a key lawsuit, as being the percentage of a single list of 50 phonetically balanced words at a single (but unspecified) level, presented in quiet, that were incorrectly repeated. Thus was a legal precedent established, and we foresee years of hard work before this preposterous principle can be given a proper burial. . . . To sum up, then, no handicap system is either valid or invalid, because no validating principle has been accepted – at least none that can actually be used. Obviously, any departure from 0 dB HL (or, for that matter, from –10 dB HL) will sometime, somewhere, result in someone missing some important auditory cue. So handicap, especially its low fence, must continue to be arbitrary. Like the quest for ‘absolutely normal hearing’, the quest for the ‘true measure of handicap’ is a quest for the Holy Grail. Neither is likely to be soon discovered.


An assessment of the then state of knowledge of the effect of noise on hearing by an experienced top-level scientist:
The negative tone of the foregoing discussion, which points out the shortcomings of the audiometric data on humans and particularly emphasises the questionable manipulations of these data that have been performed, is not accidental. Because of the combined effects of (1) gatherers of audiometric data who feel that when the pile of audiograms reaches a certain height it must be worth publishing, (2) investigators who mistake coexistence for causation, (3) bureaucrats who want to emphasise dangers of every possible noxious influence so that more regulation is required, necessitating bigger staffs, (4) a sensational press, and (5) a citizenry inclined to believe the worst about whatever they dislike, the hazards of noise have been somewhat exaggerated in the last couple of decades, so the intent of the present discussion is to try to pull the situation back into perspective and to make it clear that present noise regulations are usually arbitrary and occasionally capricious. It is reasonably certain that 10 years or more of exposure to steady industrial noise, 8 hours/day, 5 days/week, 50 weeks/year, can produce an effect, measurable in population averages if the noise level is 85 dB(A) or higher, in some individuals if the level exceeds 90 dB(A), with the rate of growth of hearing loss and its severity increasing rapidly as 90 dB(A) is exceeded. Therefore the widespread adoption of 90 dB(A) as a practical 8-hour exposure limit is a reasonable course of action, especially when this is coupled with monitoring audiometry to identify the most susceptible ears – or perhaps those exposed to the greatest socioacusic influences. When daily exposures are shorter than 8 hours, or intermittent, even less effect is found than one would predict on the basis of the equivalent energy absorbed by the ear. Hearing, then, is a resilient biological system that, although capable of being overdriven and permanently damaged by exposures above certain values, is likewise able to recover from exposures below these values. It is unfortunate that we have not yet been able to determine precisely what these ‘certain values’ are.


All actual field studies of non-industrial noise-exposed 20-year-olds have found median hearing threshold levels (HTLs) of at least 3–5 dB at most test frequencies. It is clear, therefore, that tables or graphs that purport to show realistic HTLs to be expected in a group of workers at a particular age if their industrial noise exposures have had no effect must consist of Age Corrections added to the actual HTLs of the 20-year-olds.


Effect of noise pattern on noise-induced permanent threshold shifts:

It is possible to establish limits for exposures that are continuous; time-varying; interrupted; intermittent; interrupted and intermittent; interrupted and time-varying; or interrupted, intermittent and time-varying; and, of course, for the single
short event. These limits will depend on the criterion tolerable damage, the
spectrum of the noise, and the duration of noise bursts and pauses as well as the
sound level, duration, and perhaps crest factor . . . Selection of a specific limit as
being a tolerable daily exposure, for example 90 dBA, therefore implies acceptance
of some degree of hearing loss, and the question at that point relevant to limits for
other patterns of exposure becomes: ‘What intermittent and/or time-varying
exposures are equivalent in effect to the 8-h exposure at 90 dBA?’ Three main
answers to this question have been proposed: (1) exposures of equal energy, (2)
exposures that produce the same TTS, and (3) exposures of the same time-weighted
average (TWA). The equal-energy theory, formally adopted in AFR 160-3 (1956) and
by the International Organization for Standardization is . . . the most attractive
because of its simplicity . . . Halving the exposure time and doubling the intensity
(increasing the level by 3 dB) would keep the level constant . . . The equal-TTS
principle . . . is complicated to apply . . . So the 1966 CHABA recommendation of
exposure limits based on the equal-TTS principle has not found wide acceptance,
although the fact that intermittent exposures produce less TTS than continuous
ones has influenced some other proposed limits. In particular, this evidence led to
the adoption of the time-weighted average (TWA) by OSHA, in which the trading
relation between level and time is 5 dB per halving (OSHA, 1983). (at p. 164)

WARD WD, GLORIG A (1961) A case of firecracker-induced hearing loss. Laryngoscope 71:
1590–6.

Ability to demonstrate effect of a noise hazard with ‘before’ and ‘after’
audiograms.

Society of America 31: 1138.

Apparent gender differences in susceptibility to noise damage: ‘the
present results strengthen the hypothesis that differential exposure, rather
than differential susceptibility, is responsible for the observed differences
between men and women in auditory sensitivity’.

WARD WD, SANTI PA, DUVALL AJ III, TURNER CW (1981) Total energy and critical inten-

Experimental demonstration that single continuous noise exposures
damage hearing in conformity with the total energy principle – equal
amounts of energy produced equal damage.

WAUGH, R (1973) dB(A) Attenuation of ear protectors. Journal of the Acoustical Society of

Noise spectra obtained in Australian industry are accompanied by
the difference between the C-weighted and the A-weighted mean
levels.

Tinnitus associated with noise exposure: among 33 cases of hearing loss due to gunfire, 15 had ‘slight tinnitus’, and 16 ‘persistent’ tinnitus. Note that occupational noise damage (chronic, as opposed to acute, noise exposure) to the hearing shows a different pattern.


Sweep frequency continuous test tone Békésy audiometry was more sensitive in detecting noise damage to hearing than manual discrete frequency audiometry.


A tendency for audiometer operators to register the hearing levels that they expect to apply to their subjects is a problem specific to manual audiometry.

After having checked over audiograms . . . submitted during the past several years, the writer has been interested in the exceedingly high percentage of these hearing charts which registered acuity thresholds falling almost exactly on the zero line or line for ‘normal hearing’ . . . When audiograms representing a large number of subjects fail to show a reasonable dispersion of thresholds, one may well wonder exactly how precise a measurement of hearing the pure tone audiometer test constitutes. When these audiograms follow quite closely a more generally used norm . . . a further doubt of the absolute objectivity of the pure tone test arises.


Evidence for viruses causing a sudden hearing loss.


Presbyacusis was characterized clinically by ‘presence of tinnitus’ (a study based upon patients drawn from a hearing aid clinic and geriatric hospital wards).


(a) The use of the term ‘normal’ to describe the modal threshold of stringently audiologically cleansed young servicemen has bedeviled interpreta-
tions of audiograms ever since (this Royal Air Force study was used as the basis for the standardization of audiometers). (b) The Royal Air Force did not measure thresholds of hearing at the frequency of 6 kHz in that particular study. (c) Used Standard Telephones and Cables ST&C 4026 earphone.


There was an appreciation, even in 1966, that there was variability in the properties of the TDH39/MX41-AR earphone:

The design of the TDH39 has been changed in detail from time to time, and it is possible that this may give rise to discordant threshold data. The two earphones used in the present work were in fact dissimilar; the first was one of a batch purchased in 1959 while the second was of more recent manufacture, acquired in 1964. Since there was no highly significant difference (this would appear to imply that there was a significant difference, but it was not highly significant) between the data for the two earphones, results have been pooled and only the means given.


There is a need to distinguish between symptoms – spontaneously reported to the doctor – and semeions – elicited only by direct questioning. The distinction is important for diagnosis and assessing disability, handicap, loss of quality of life, and management, including rehabilitative needs.


Diagnostic methods: ‘no solution of a . . . clinical case is accomplished pursuing a unilineal course’ (at p. 342).


Possibilities and mechanisms for occupational noise contributing to accident rates. High noise levels may be associated with higher accident rates. The possible mechanisms for such an effect includes the role of noise in causing a lack of attention and the masking of important auditory signals, such as warning shouts, sirens and machinery sounds, which may indicate impending danger. Moreover, the effects of noise damage to hearing and the need to wear HPDs to counter noise could contribute indirectly to accidents by interfering with auditory communications.

The presence of dizziness is not necessary for the diagnosis of endolymphatic hydrops.


The standard of mathematical competency to be expected of all who have attained the age of 14 years in the UK: includes appreciation of meaning of scattergraphs, correlation, and lines of best fit.


The ‘Black Book’ ignores impairment measures and other factors governing disability: ‘Their existence runs contrary to the hypothesis that hearing loss is a unique determinant of disability, or “surrogate” of disability’. In a prior publication (Davis, 1987) the Medical Research Council’s Institute of Hearing Research had said that hearing disability depends not only on hearing threshold level but also on age, sex, and tinnitus annoyance.


An approach to the assessment of cases of alleged occupational noise-induced damage to hearing adopted by an experienced medical examiner. (a) Useful tables (primarily based upon values adopted by Medical Research Council during its National Study of Hearing) (Tables 1, 2, 3 and 4) presented for the estimation of an individual’s noise exposure from his occupational history, uncertainty for gunfire exposure being reflected in the differences between Tables 3 and 4. (b) The bounds of normality:

The range of normality (or the onset point of abnormality) in physiological measurement is usually taken to be two standard deviations, or from the 2.5 percentile to the 97.5 percentile . . . If the hearing threshold levels are within the range of normality for an identical non-exposed population, this does not necessarily mean that the subject has not had noise-induced hearing loss. It is possible that the age effect on hearing has overtaken any earlier noise-induced hearing loss. (at p. 54)

(c) The diagnosis of occupational noise-induced hearing loss: ‘The diagnosis of noise-induced hearing loss can only be made from the pattern of the audiogram’ (at p. 47).
(d) Audiometric pattern:

Burns and Robinson (1970) . . . established beyond doubt that noise-induced permanent threshold shift was nearly always greatest at 4 kHz and less either side of this frequency, and that it was always the first feature to appear (nevertheless recognising individual deviations with dips at 3 or 6 kHz). The dip first deepened and later flattened off as the hearing levels at other frequencies began to catch up . . . A dip (or notch) pattern was present in all but 2% of this material (Robinson, 1984). Notch frequency and depth were highly correlated between left and right ears. An asymmetrical audiometric pattern is generally evidence against the diagnosis of chronic occupational noise-induced hearing loss, as is the comparative pattern of threshold shift in the low–mid frequencies and the high frequencies (Robinson, 1985) resulting in the ‘low tone loss’ or ‘flat loss’ type of Klockhoff, Drettner and Svedberg (1974). (at p. 47)


The importance of central (brain) auditory factors in hearing ability of older people, which factors are not reflected in the conventional audiogram.


Drawing attention to what has become known as otic blast injury.


The value of tuning fork tests to the clinician. This is a study that has been cited as dismissing their value but this study was conducted (a) using a type of tuning fork that is not suited to these methods of testing, (b) using test procedures that clinicians would not use, (c) using an experimental model that does not reflect the use of these tests by clinicians, (d) on children only, and (e) by two professionals who were not medically qualified.


Science is not an extension of common sense; much is counter-intuitive and unexpected: many illustrations to demonstrate this, for example if one bullet dropped from the hand and another fired horizontally from a gun at the same time, both hit the ground at the same instant (because rate of fall independent of horizontal motion).

Definition of the terms on which World Health Organization’s *International Classification of Impairments, Disabilities, and Handicaps* was based.


Origin of earpits. The incomplete persistence of the first branchial cleft (ancestral gill).


Definitions of impairment, disability, and handicap.


The effects of noise. These are listed in Chapter 3 as interference with communication, pain, sleep disturbance, stress response, circulatory system responses, the startle reflex in orienting response, effects on equilibrium, fatigue, general health, mental health, and annoyance (at pp. 47–66). There is no mention of tinnitus in this 103 page report, although (a) the document covered noise-induced hearing loss; (b) the first draft had been prepared by a 17-member study group; (c) the document had been reviewed and revised by a differently constituted 15-member WHO Task Group on Environmental Health Criteria for Noise.


In this successor (Beta-1 draft ICIDH-2) to the 1980 WHO ICIDH, all concepts (specifically the three dimensions of disablement) are now operationally defined. Disablement is seen as an interaction/complex relationship between the health condition and the contextual factors – environmental and personal factors. The dimensions have been designated by ‘neutral’ terms and both positive and negative aspects of each dimension have been addressed (for example, impairment/structure or function, activity/limitation in activity, and participation/restriction in participation). The impairment (I) dimension level refers to the body (or

\[175\] A revision of the WHO 1980 International Classification of Impairments, Disabilities, and Handicaps (ICIDH), which was then being subject to systematic field trials and further consultations; to come into effect in 2000.
body parts) as a basic construct. Hence ‘I’ is classified in two sections referring to (a) functions,\textsuperscript{176} and (b) structures. (Although organ level was mentioned in the 1980 version of ICIDH, the definition of an ‘organ’ is not clear. The eye and ear are traditionally considered as organs; however it may be difficult to identify and define the boundaries of extremities and internal organs. Instead of an approach by ‘organ’ which implies the existence of an entity or unit within the body, ICIDH-2 replaces this term with body structure.) ‘Disabilities’ has been replaced by the \textit{activities} (A) dimension. This classification is based solely on ‘activities’ of the person, which are actual performances. So the unfruitful debates over ‘can do’ versus ‘does do’ or ‘might do’ have been resolved. ‘Handicap’ has been formulated by participation. This has introduced a ‘positive’ connotation and conception of this dimension. The participation (P) dimension has been classified according to ‘domains’ of major areas of life, rather than summary dimensions as was the case with the previous handicap classification. This approach allows better identification of the problems/restrictions (for example, barriers, hindrances) or advantages (for example, enhancers or facilitators) in different domains, and it is hoped that this will give rise to practical solutions to achieve better participation from people with disabilities. The concepts in the ICIDH concern problems related to ‘deviation from norms’. For quantifiable phenomena, statistical concepts of the ‘norm’ may be useful to identify the scale of the deviation.


The full document can be accessed at \url{http://www.who.int/icidh} in English and in a number of other languages.


How the clinician goes about diagnosis: a pattern recognition exercise. The book contains more than 170 colour photographs to give various views (reflecting different disease processes) on examining the ear with an otoscope. There are no formulae or equations.


\textsuperscript{176} In the early understanding of the ICIDH, as proposed in 1975, functional limitations were regarded as being elements of disability, whereas they are here assimilated with impairments.
Investigation of intra- and inter-observer variation using photographs that showed various patterns of chronic otitis media. This would be seen by otoscopy and reflects a classification that had been proposed by the senior author: ‘all the trainees had seen many textbook photographs and examined many normal and pathological ears before the first test session, yet the error rates were unacceptably high; after the course the overall error rate fell from 44 to 21% . . . the error rate in assessing ear [disease] activity fell from 35 to 17%’.


(a) The complexity of the biochemical reactions that produce programmed cell death, which is the basis for ageing changes. The initiating stimuli may arise from at least three cell structures – the nucleus, the mitochondria or the cell membrane. These events ultimately converge in the activation of the caspase enzymes (cysteine proteases), which results in cell death. (b) Although it might be argued that chronic noise damage to hearing (occupational noise-induced hearing loss) accentuates the ageing process in the part of the cochlea that is ‘tuned’ to 4 kHz, it is difficult to see how acute noise damage – acoustic trauma and otic blast injury – would work through this process.


The biological mechanism of ageing (apoptosis) being distinct from mechanisms of occupational noise-induced hearing loss.


Complexity and interindividual variability of extent and manner in which people deal with upsets and stresses.


Reported difficulty in understanding speech in a background of noise is not related to frequency resolution or sensitive measures of ‘subtle cochlear damage’ – it is not what one would expect to be the case if King–Kopetzky syndrome were attributable to noise damage to the ear.


177 Oncosuppressor (cancer suppressing) protein p53.
Clinical features of King–Kopetzky syndrome. ‘The main findings are that complaints were commonly focussed on the categories of “live speech” and “electronic speech” difficulties . . . psychological problems were related to anxiety.’ There were significantly fewer problems with warning signals than was the case with other patients.


A procedure based on critical band analyses of sounds for calculating loudness of sounds; used for Method B in BS 4198.


Defining critical bands of sounds so that they could be useful for loudness calculation procedures, for example Method B in BS 4198.


Experimental demonstration that financial reward to an individual can bring about an improvement in the threshold of hearing. [If financial reward were in the opposite direction, and the rewards for poorer hearing were potentially immeasurably greater, what effect would this have on the measured threshold?]

References


178 A method for calculating loudness.


Web sites not mentioned previously

http://www.assiniboinec.mb.ca/user/downes/fallacy/posthoc.htm
Date: 1997.

Coincidental correlation (*post hoc ergo propter hoc*). One cannot assume that any auditory symptoms (hearing difficulties, tinnitus, hyperacusis) associated with previous or concurrent chronic potentially hazardous noise exposure are due to such exposure, although a temporal relationship to acute hazardous noise exposure would predicate such assumption on a heuristic basis; accepting an argument that someone’s auditory symptoms must be due to previous noise exposure merely on the basis that, statistically, an effect on hearing can be demonstrated, even in the millibel range, would demand that one accepts that, if no potentially hazardous occupational noise exposure can be demonstrated, then such symptoms must be due to ageing, or, if in a young man, then to the gender factor, or if in a woman who would be classified as a manual worker, then to the socio-economic factor.179

179 Statistical data indicate that the same shift in threshold (about 3 dB averaged over the four frequencies 0.5, 1, 2 and 4 kHz) is associated with being a man (NPL Ac 61), or a manual worker (Medical Research Council’s Institute of Hearing Research), or aged 38 years (ISO 7029) or having been exposed to an equivalent continuous sound level of 93.5 dB(A) for two years (NPL Ac 61); but what clinician would diagnose gender-associated hearing loss, socio-economic hearing loss or (in a 38-year-old man) presbyacusis? This statement applies to the 50 percentile (median) in the distributions for the ageing and the noise factors but even at the fifth percentile neither of these factors reaches the 20 dB criterion for producing a hearing loss. Awareness of this explains why the majority of noise-induced permanent threshold shifts in the population at large are asymptomatic – one is dealing with a subclinical condition.

180 Requires 5 Mb disk space.
http://www.u.arizona.edu/~jkandell/music/stock/stock_prem.html
Date: 1997.
Choppers and strings – Stockhausen’s *Sound of Music*. Aesthetic aspects of noise:

At a given signal, engines splutter and whir into life, the strains of one violin, and then another, mix with the beating of rotor blades, and together they rise into the air . . . The beating helicopter rotors mix with the music from four stringed instruments – two violins, a cello and viola – aboard four aircraft . . . the Grasshoppers, a unit of the Royal Dutch Air Force, specially trained in delicately manoeuvring the French Alouette helicopters . . . the pilots have a . . . melodic role – turning and banking the helicopters to change the pitch and the speed of the whirring.

http://www.physiol.ucl.ac.uk/ashmore/jfa.htm
Date: 1998.
The active mechanism of hearing. A vivid sound movie\textsuperscript{180} demonstrates active movement of the outer hair cells of the cochlea (by means of the outer hair cell motor) in response to a sound stimulus acting upon them.

http://www.davidmarshall.co.uk/cpr.html
Date: 1999.
An easily accessible and downloadable version of the new UK Civil Procedure Rules. A London barrister has consolidated the rules into a single file in Microsoft Word format, which is available as an uncompressed 768 kbyte (238 pp.) Word document. Part 35 covers ‘Experts and Assessors’, proceeding from Rule 35.1 (duty to restrict expert evidence) to Rule 35.14 (expert’s right to ask court for directions). Rule 35.3 states that the expert’s overriding duty is to the court. Rule 35.10 deals with the contents of the report.

http://www.military.ie/main\%20Section\%20Pages/Corps\%20Information/Infantry/infantry.htm

http://www.military.ie/main\%20Section\%20Pages/Weapons\&Equipment/Artillery/weapons\_Artillery.htm
Date: 1999.
Listing of the military weapons in use by the Irish Army: includes the Steyr Aug A1, the 7.62 mm FN MAG, the AI 92, the Hotchkiss-Brandt 60 mm mortar and 81 mm LMLB, the Carl-Gustav 84 mm, the 12.7 mm Browning HMG, the Milan ATGW, the L118 105 mm, the 25 pounder, the AM50 120 mm, the RBS 70 SAM, the L60 and L70 40 mm ADGs.
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PART II
Some Acts, Regulations and Standards Relevant to Hearing and to Noise
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Note: the prefix ISO or IEC means that the standard is an international one. An international standard prefixed by EN means that Europe has adopted the standard. If an international standard is prefixed by BS it means that that standard has been adopted by the UK and that BSI is providing the English language version of that standard.


Applies to sound insulation between a pair of rooms. Determines the steady state $\frac{1}{3}$ octave band filtered white noise level difference and the receiving room equivalent absorption area from which the standardized level difference is derived. The results can be used to determine whether building elements have met acoustic specifications, for example building regulations.


Applies to the sound insulation of a building facade with respect to external noise such as traffic noise. The sound source for the steady state $\frac{1}{3}$ octave band filtered level difference can be either the existing traffic noise or noise from a loudspeaker. The results, expressed as either sound reduction index or standardized level difference, can be used to determine whether facades have met acoustic specifications.


Measures impact noise transmissions through floors using a standardized tapping machine. The steady state $\frac{1}{3}$ octave band filtered receiving room sound pressure level is measured while the impact sound is tapping on the test floor. Determines the receiving room equivalent absorption area and derives the normalized impact sound pressure level. The results can be used for design and comparison of floors.


Measures the impact sound insulation between a pair of rooms. The steady state $\frac{1}{3}$ octave band filtered receiving room sound pressure level is measured while a standardized tapping machine is hammering on the test
floor. Determines the receiving room equivalent absorption area and derives the normalized/standardized impact sound pressure level. The results can be used to determine whether floors have met acoustic specifications, for example building regulations.

BS 3045: 1981. Method of expression of physical and subjective magnitudes of sound or noise in air

Conversion of loudness level in phons to loudness scale in sones. Defines sound pressure level and sound power level. It also deals with the conversion of loudness level in phons to loudness scale in sones and defines sound pressure level and sound power level. Technical equivalent of ISO 131.

BS 3383: 1988. Specification for normal equal-loudness level contours for pure tones under free-field listening conditions

Specifies, for the condition of equal loudness and certain other stated conditions, relationships between sound pressure levels and frequencies of pure continuous tones. These are expressed by a bilinear equation for the preferred frequencies in the one-third octave series from 20 to 12500 Hz. A graphical illustration is included. Technical equivalent of ISO 226: 1987.

BS 4009: 1991. Specification for artificial mastoids for the calibration of bone vibrators used in hearing aids and audiometers

Basic features for objective calibration of bone vibrators. Technical equivalent of IEC 373: 1990 which has become IEC 60318-6.

BS 4142: 1997. Method for rating industrial noise affecting mixed residential and industrial areas

Gives British Standard methods for rating industrial noise affecting mixed residential and industrial areas. There are three separate stages to the rating procedure: (a) measurement of the intrusive noise, (b) measurement of the background noise, and (c) comparison of the level of the intrusive noise with that of the background noise. The foreword to this standard emphasizes the subjective nature of response to noise and that likelihood of complaint depends on many factors, although likelihood increases as difference between rating level and background noise level increases. The standard deals only with the degree to which rating level

181 Confirmed in 1983.
182 This is what the standard is about, i.e. not about loudness, noisiness, annoyance or even nuisance.
exceeds background noise level. The standard is only a part of a complete noise assessment.

**BS 4196: Part 0: 1981. Sound power levels of noise sources. Guide for the use of basic standards and for the preparation of noise test codes**

**BS 4196: Part 1: 1991. Sound power levels of noise sources. Precision methods for determination of sound power levels for broad-band sources in reverberation rooms**

**BS 4196: Part 2: 1991. Sound power levels of noise sources. Precision methods for determination of sound power levels for discrete-frequency and narrow-band sources in reverberation rooms**

**BS 4196: Part 5: 1981. Sound power levels of noise sources. Precision methods for determination of sound power levels for sources in anechoic and semi-anechoic rooms.**

**BS 4196: Part 7: 1988. Sound power levels of noise sources. Survey method for determination of sound power levels of noise sources using a reference sound source**

Useful for equipment that cannot be removed for acoustical testing.


**BS 4198: 1967. Method for calculating loudness**

Procedures for calculating the loudness of sounds experienced by a typical listener. Method A, which uses octave band analyses of sound, is based upon the reports by Stevens (1956; 1957). Method B, which uses critical band analyses of sound, is based upon the reports by Zwicker (1960; 1961). Method A is designed specifically for the types of broad band spectra most commonly encountered. Method B may be used with all types of spectra. Both procedures are designed for noises that are steady rather than intermittent. Technical equivalent of ISO 532: 1975.

(replaces BS 4669: 1971; technically equivalent to IEC 60318-1: 1998)

Specifies requirements for an artificial ear intended for the calibration of supra-aural earphones.


An acoustic coupler for loading an earphone with a specified acoustic impedance for calibrating supra-aural earphones used in audiometry.

BS 4813: 1972. Method of measuring noise from machine tools excluding testing in anechoic chambers
Relates to procedure for carrying out tests for continuous noise of machine tools. Deals with general conditions, for example room suitability and background noise, and with the measuring process, for example instrumentation, measuring points, units of measurement etc., and gives details of a standard format for the statement of results. Where appropriate, the standard accords with BS 4196.

This gives a standardized subjective method for measuring the sound attenuation (reduction of sound intensity) of hearing protectors. Replaced by BS EN 24869-1: 1993.

BS 5330: 1976. Method of test for estimating the risk of hearing handicap due to noise exposure
Specifies a relationship between noise exposure and the expected incidence of hearing handicap.\(^{183}\) The exposure is derived from the equivalent continuous A-weighted sound level during an eight-hour working day. The hearing of a person is deemed to be impaired sufficiently to cause a ‘handicap’ if the arithmetic average of the hearing threshold levels, of the two ears combined, at 1 kHz, 2 kHz and 3 kHz, is equal to or greater than 30 dB (re BS 2497). ‘Since this standard is based upon statistical data it cannot be expected to provide an accurate assessment of hearing handicap in individual persons.’

BS 5555: 1993. Specification for SI units and recommendations for the use of their multipliers and of certain other units

\(^{183}\) This would now be referred to as a ‘hearing disability’.
BS 5966: 1980. Specification for audiometers
This replaced BS 2980 and was replaced by BS EN 60645.

BS 5969: 1981


BS 6402: 1983. Personal sound exposure meters
Replaced by BS EN 61252: 1997.

BS 6655: 1986. Specification for pure tone air conduction threshold audiometry for bearing conservation purposes
Procedures and requirements for audiometry, without masking, using either an automatic recording fixed frequency audiometer or a manual one. Bracketing and ascending procedures are given for the latter. Equivalent to ISO 6189-1983.

BS 6698: 1986


General terms for components.

Method for the rating of speech transmission in auditoria, with or without sound systems.

BS 6950: 1988
BS 7025: 1988. Method for preparation of test codes of engineering grade for measurement at the operator's or bystander's position of noise emitted by machinery
Applicable to outdoor and indoor measurements, and to operator positions that are in the open or partially or totally enclosed. Technically equivalent to ISO 6081.

BS 7113: 1989

BS 7189: 1989. Specification for sound calibrators
Performance requirements for class 0, class 1 and class 2 calibrators under specified conditions. The techniques of calibration for the calibrator and any associated device or system are excluded. Equivalent to IEC 942: 1988. Now replaced by BS EN 60942: 1998.


Gives guidance on the way noise limits should be specified and on methods to verify whether or not they have been complied with. Equivalent to Part 3 of ISO 1996: 1987.

Specifies a set of tests for the periodic verification of compliance of a sound level meter with BS 5969 or BS 6698.


184 Of course, this cannot be so as the data reflect the effects of ageing (as the standard intends).
Specifies a shortened verification test procedure for type 2 sound level meters, which are used for general field applications.

BS 7636: 1993. Sound field audiometry with pure tone and narrow-band test signals

Recommendations for the control of noise in and around buildings. Incorporates the results of research and experience gained over the previous 20 years. Provides up-to-date information on the rating of noise and the rating of the sound insulation of building elements.

BS EN 352-1: 1993. Hearing protectors. Safety requirements and testing. Ear muffs
Does not deal with ear muffs within, or for attachment to, a helmet or with electronic or amplitude sensitive devices.

Does not deal with electronic or amplitude-sensitive ear plugs.

BS EN 352-3: 1997. Hearing protectors. Safety requirements and testing. Ear muffs attached to an industrial safety helmet
Specifies constructional, design and performance requirements, test methods, marking requirements and user information.

Guidance to suppliers, purchasers, safety authorities and wearers.

A method using a plenum of defined height mounted above an acoustical barrier, which separates two rooms of a specified test facility.

Applies to building elements excluding windows and doors, with an area of less than 1 m², which occur in a certain number of discrete sizes with
well-defined lateral dimensions and that transmit sound between two adjacent rooms or between one room and the open air independently of the adjoining building elements.

Determination of the sound absorption coefficient of acoustical materials used as wall or ceiling treatments, or the equivalent sound absorption area of objects, such as furniture, or persons, in a reverberation room. Not intended for measuring the absorption characteristics of weakly damped resonators.


Method for measuring sound attenuation at the threshold of hearing, giving consistently reproducible values that are close to the maximum attainable but are unlikely to be achieved in use. Technically equivalent to ISO 4869-1.

For quality inspection purposes and to investigate production spreads of performance and changes with age.

**BS EN 60268-7: 1996. Sound system equipment. Headphones and earphones**
Specifies the characteristics and methods of measurement and includes a classification and code for marking for headphones, headsets, earphones and earsets for use on, or in, the human ear.

**BS EN 60268-16: 1998. Sound system equipment. Objective rating of speech intelligibility by speech transmission index**
Defines the STI, STITEL and RASTI objective methods for rating the transmission quality of speech with respect to intelligibility and the correlation of results from the different methods.

Specifies requirements for audiometers designed to present pure tones to a subject in a standardized manner. Equivalent to IEC 60645-1.
Specifies requirements for audiometers designed to present speech sounds to a subject in a standardized manner, for example for the measurement of speech recognition. Equivalent to IEC 60645-2.


Specifies requirements for equipment in the frequency range 8000 Hz to 16000 Hz. Equivalent to IEC 60645-4.

BS EN 60651: 1994. Specification for sound level meters

BS EN 60804: 1994. Specification for integrating-averaging sound level meters
Characteristics of meters for the measurement of the equivalent continuous sound pressure level \( L_{eq} \) of steady, intermittent, fluctuating and impulsive sounds. Gives tests to verify accuracy and stability to ensure that differences in measurements, taken with various makes and models of instrument, are reduced to a practical minimum. Formerly BS 6698: 1986. Identical to IEC 60804: 1985.

Equivalent to IEC 60942: 1997.

BS EN 61027: 1993
Specification for instruments for the measurement of aural acoustic impedance/admittance. Equivalent to IEC 61027.


BS EN 61265: 1995. Electroacoustics. Instruments for measurement
of aircraft noise. Performance requirements for systems to measure one-third-octave band sound pressure levels in noise certification of transport-category aircraft

Requirements for the electroacoustical performance of instruments used to measure aircraft noise for certification purposes.


Specifies reference equivalent threshold sound pressure levels for Beyer DT 48 and telephonics TDH 39 earphones in a coupler complying with IEC 303, together with other supra-aural earphones, meeting stated requirements, in an artificial ear complying with IEC 318.

Note that the term ‘normal’, which appeared in the title of the first British Standard (BS 2497: 1954) was subsequently deleted. The original samples (Royal Air Force, National Physical Laboratory) on which the standard was based provided modal values for a clinically otologically normal population. The individual subjects, having had a prior screening audiogram, were tested with a precision 2 dB step audiometer. Note that this standard is one to which audiometers should conform, not individuals.


Specifies a standard refernce zero for the calibration of pure tone bone conduction audiometers


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185 Formerly BS 2497: 1992.
186 Not random samples of the general population.
BS EN ISO 389-5: 2001. Acoustics. Reference zero for the calibration of audiometric equipment. Reference equivalent threshold sound pressure levels for pure tones in the frequency range 8 kHz to 16 kHz


Method of deriving a single-figure rating of the impact sound insulation performance of buildings and of building elements by comparison with a standard reference curve. Applicable to measurements made according to BS 2750, Parts 6, 7 and 8.


The standard dealing with methods for performing audiometry. It also covers methods (biological and physical) and frequency of calibrations as well as standards for maximum permissible ambient noise levels for audiometric test rooms.

Specifies test signal characteristics and procedures for determining hearing threshold levels in the range 125 Hz to 12 500 Hz.

BS EN ISO 11200: 1996. Acoustics. Noise emitted by machinery and equipment. Guidelines for the use of basic standards for the determination of emission sound pressure levels at a workstation and at other specified positions

BS EN ISO 11201: 1996. Acoustics. Noise emitted by machinery and equipment. Measurement of emission sound pressure levels at a work station and at other specified positions
Engineering method in an essentially free field over a reflecting plane.

BS EN ISO 11203: 1996. Acoustics. Noise emitted by machinery and equipment. Determination of emission sound pressure levels at a work station and at other specified positions from the sound power level


Specifies the standard reference zero for the calibration of pure tone bone conduction audiometers.


BS ISO TR 389-5: 1998. Acoustics. Reference zero for the calibration of audiometric equipment. Reference equivalent threshold sound pressure levels for pure tones in the frequency range 8 kHz to 16 kHz

BS ISO 8297: 1994. Acoustics. Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment. Engineering method

**Code Of Practice For Reducing The Exposure Of Employed Persons To Noise. (1972) London: HMSO.**
Specific advice to employers on methods for controlling, measuring and recording noise levels, together with advice on hearing protection for workers. It specifies a maximum noise level to which workers should be exposed, 90 dB(A).

**Disability Discrimination Act 1995**
An Act that makes it unlawful to discriminate against disabled persons in connection with employment, the provision of goods, facilities, and services, or the disposal or management of premises. Makes provision for the employment of disabled persons. Defines *disability* and *disabled person.*

**EC Directive 79/113/EEC**
Deals with determining sound power level.

**EC Directive 81/1051/EEC**
Deals with measuring operator position noise.

**EC Directive 86/188/EEC**
Deals with the protection of workers from the risks related to exposure to noise at work.

**EC Directive 89/392/EEC**
Requires all machinery manufacturers (from small domestic appliance manufacturers to those of large diesel engines) to provide noise emission information as part of the process of conformité Européenne (European conformity) marking and declaration of conformity. A product displaying the CE marking accompanied by the correct formalities can be traded in every country of the European Economic Area.

**EN 26189: 1991**

**EN 27566: 1991**
EN 28798: 1991
Acoustics – reference levels for narrow band masking noise.

Firearms Acts 1968–97
The laws in England and Wales that govern the civilian use of handguns, the latest at the time of publication being the Firearms (Amendment) (No. 2) Act 1997.


IEC 225: 1966
Specification for octave, half-octave and third-octave band pass filters intended for the analysis of sounds and vibrations.

IEC 645-1: Audiometers Part 1: Pure Tone Audiometers
Standard for various categories of audiometers, giving facilities that must be provided. Now IEC 60645-1.

IEC 651: 1979
International standard for sound level meters, which, together with IEC 804, will be replaced by IEC 61672.

IEC 804: 1985
International standard for integrating-averaging sound level meters, which, together with IEC 651, will be replaced by IEC 61672.

IEC 942: 1988
The international standard for sound calibrators until 1997 when replaced by IEC 60942.

Specifies requirements for an artificial ear intended for the calibration of supra-aural earphones.

\[^{187}\] Now referred to as ICIDH-1 with the advent of ICIDH-2.
An acoustic coupler for loading an earphone with a specified acoustic impedance for calibrating supra-aural earphones used in audiometry

IEC 60373: 1990 Mechanical coupler for measurements on bone vibrators (will become IEC 60318-6)

IEC 60942: 1997
The international standard for sound calibrators. As well as providing specifications for sound calibrators, it gives test methods for both pattern evaluation of new models of instrument and periodic evaluation of individual devices.

IEC 61672
The new International Standard for sound level meters, which supersedes IEC 651 and IEC 804.

ISO 31-0: 1992. Quantities and units – Part 0: General principles
Inter alia, provides for a decimal sign being denoted as a comma; accepts both a cross and a half-high dot as a multiplication sign. Thousand marker to be denoted by a space (never by a comma or a point).

ISO 31-1: 1992 Quantities and units – Part 1: Space and time

ISO 31-7: 1992 Quantities and units – Part 7: Acoustics

ISO 389: 1991

ISO/R507: 1970
International Standard for describing noise around an airport.

ISO 532: 1975
International Standard for methods for calculating the loudness of noises.

ISO 1000: 1992. SI units and recommendations for the use of their multipliers and of certain other units
Basic quantities for use in describing noise in community environments and basic procedures for determining them.


Gives guidance on the way that noise limits should be specified and on methods to verify whether or not they have been observed.

The International Standard for the determination of occupational noise exposure and estimation of noise-induced hearing impairment. Note (a) interdiction against using statistical data to assess the hearing of individuals: ‘This International Standard is based on statistical data and therefore shall not be used to predict or assess the hearing impairment or hearing handicap of individual persons’ (at p. 1). (b) Defines an ‘otologically normal population’ as a ‘highly screened population’ (at p. 1). (c) Does not use the noise immission level concept. (d) Uses a compressive (less than additive) model for the interaction of the age and noise factors. (e) Importance of high frequencies: none of the nine ‘commonly used or proposed equations for the assessment of hearing handicap (“disability” in WHO and UK terminology) for conversational speech’ that are given in ISO 1999: 1990 includes any frequency higher than 4 kHz.

ISO 6189-1983
The international standard specification for pure tone air conduction audiometry for hearing conservation purposes:

0 Introduction This International Standard lays down requirements and procedures for conducting pure tone air conduction audiometry when it is deemed by the responsible authority to monitor the hearing of subjects exposed to noise at work . . . Methods of conducting audiometric tests with manual and automatic

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\(^{188}\) Not yet endorsed by the UK.

\(^{189}\) For the Rudmose audiometer, which is used in industry, not the sweep frequency Békésy audiometer, which is used for clinical diagnostic purposes.
recording fixed frequency\textsuperscript{189} audiometers are presented in this International Standard. . . 2 Field of Application . . . The specifications in this International Standard are not intended for clinical purpose\textsuperscript{190} . . . 8.2 Determination of hearing threshold levels in automatic recording audiometry . . . Average the peaks and (the) valleys of the tracing...This mean value, rounded up to the nearest whole number in decibels, is taken as the hearing threshold level at that frequency and that ear . . . 9.2 Comparison of Audiograms . . . To compare audiograms which have been recorded by automatic recording and manual audiometry, 3 dB should be added to the hearing threshold levels determined by means of automatic recording audiometers.


ISO 9612: 1997 Acoustics – Guidelines for the measurement and assessment of exposure to noise in a working environment

ISO CD 10843
Draft international standard outlining various methods for the measurement of impulse noise.


The Supply of Machinery (Safety) Regulations 1992 (as amended in 1994) The supplier of new machinery needs to provide:

- a ‘Declaration of Conformity’, usually supplied by the manufacturer;
- CE marking;
- instructions for safe installation, use and maintenance of the machinery;
- information on noise emissions, including:
  - sound pressure level at workstations; where this exceeds 70 dB(A);
  - instantaneous sound pressure value at workstations, where this exceeds 63 pascals (equivalent to 130 dB(C) peak); and

\textsuperscript{190} Ibid.
• sound power level emitted by the machinery, where the sound pressure level at workstations exceeds 85 dB(A);
• information about the operating conditions of the machinery during measurement and what methods have been used for the measurement of the noise emissions.

*Nomina Anatomica (1989) 6th edn. Amsterdam: Excerpta Medica*

The official international list of anatomical terms that preceded the *Terminologia Anatomica*.

PART III
Glossary of Symbols, Abreviations and Terms
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Mathematical symbols

+ plus sign (addition).

– minus sign (to denote subtraction), thus different from a hyphen (–).

× multiplication sign (not the same as a lower-case x), for example $a \times b$, but normal algebraic convention is to omit this sign so that the expression is written $ab$.

/ forward slash (same as ÷, division).

· decimal point – an above-the-line dot (introduced by Leibniz in 1698 as a symbol for multiplication because the use of ‘×’ led to confusion with the letter). Sometimes shown as a full stop.

* asterisk: (a) used as an operator in computerized calculations, being the same as $\times$ or multiplication; (b) used following the name of a pharmaceutical product to indicate that the name is a trade mark; (c) used to denote a quantity that is not known or not knowable in listings of data; (d) used as a superscript – it is the usual way to denote the complex conjugate of a number.

^ caret: used as an operator in computerized calculations to denote exponentiation, for example $a^n$, such as $2^3$, viz. $2 \times 2 \times 2$. The normal algebraic convention would be to write $a^n$, where the superscripted ‘$n$’ is referred to as the exponent.

In international documents, a comma (,) is used instead of a decimal point (·) to denote the decimal position, and a space is used instead of a comma to break up a series of digits into groups of three, as in 1 000.

Symbols, abbreviations and technical terms

$\beta$ (Greek letter beta) response criterion; a measure derived from signal detection theory.

$\lambda$ (Greek letter lambda) a parameter (value dependent on frequency) in the NPL formula relating noise exposure measures to hearing threshold measures.

$\lambda$ wavelength.
µ micro- – one millionth when preceding the symbol for the unit of a quantity, for example µPa (micropascals).

σ (Greek small letter sigma) frequently used to denote the standard deviation of a set of measurements.

Σ (Greek capital letter sigma) denotes the ‘sum of’.

A (a) component of HTL associated with age; (b) sound absorption.

A duration: see pressure-wave duration.

AAHL: age-associated hearing loss192 (synonymous with ARHL and ARPTS).


AAO–HNS: American Academy of Otolaryngology–Head and Neck Surgery (successor to AAO); the current name of the organization representing specialists practising ENT and Head and Neck Surgery in the USA.


abg: air–bone gap.

ABG: air–bone gap.

ability: a term that indicates functional differences between individuals that are within the normal range.

abiotrophy: tissue degeneration with loss or disturbance of function, particularly in diseases of genetic origin.


ABR: auditory brain stem response.

ac: air conduction.

192 Having regard to the comments regarding ‘hearing loss’, this quantity should best be termed age-related permanent threshold shift in analogy with noise-induced permanent threshold shift.
AC: air conduction.

**acoustic admittance**: the reciprocal of **acoustic impedance** (British Society of Audiology, 1992); the real and imaginary components of acoustic admittance are known as acoustic conductance and acoustic susceptance.

**acoustic cochleography**: the technique whereby **otoacoustic emissions** are elicited and analysed.

**acoustic coupler**: a cavity of specified shape and volume which is used for the calibration of earphones in conjunction with a calibrated microphone adapted to measure the pressure developed within the cavity; there is an IEC specification (IEC 126) for a reference coupler relating to hearing aids, and one (IEC 303) relevant to audiometers.

**acoustic impedance**: the complex ratio of sound pressure to volume velocity through a surface (British Society of Audiology, 1992). A simplistic explanation would be to say that acoustic impedance measurements provide measures of the stiffness of the middle ear’s sound transmitting mechanism. The latter is affected by scarring or other abnormalities of the eardrum and by diseases that affect the mobility of the little bony chain (hammer, anvil, and stirrup). The stiffness may be reduced or enhanced, depending on the precise nature of the middle ear derangement. The real and imaginary components of acoustic impedance are known as acoustic resistance and acoustic reactance.

**acoustic power**: the amount of sound energy emitted by a source every second (expressed in watts); ranges from $10^{-9}$ W for a whisper to several kilowatts for a jet engine.

**acoustics**: that branch of science concerned with the study of sound.

**acoustic trauma**: the permanent loss of hearing that immediately follows a brief exposure to a very intense noise, such as gunfire.

**activity**: the term ‘activity’ is used in the broadest sense to capture everything that a person does, at any level of complexity: from simple activities to complex skills and behaviours. Activities include simple or basic physical functions of the person as a whole (grasping, moving a leg or seeing), basic and complex mental functions (remembering past events or acquiring knowledge), collections of physical and mental activities at
various levels of complexity (driving a car, personal social skills, interacting with persons in formal settings). The nature and extent of functioning at the level of the person. Activity is concerned with what happens – the practical – in a relatively neutral way. The use of assistive devices does not eliminate the impairment but may remove limitations on activity in specific domains, whereas without the assistive device, the person’s activity would be limited.\footnote{Beta-1 Draft version of ICIDH-2 (WHO).}

\textit{activity limitation}: (formerly, disability) is a difficulty in the performance, accomplishment or completion of an activity at the level of the person. The difficulty encompasses all of the ways in which doing the activity may be affected – doing it with pain, discomfort; doing it too slowly or quickly or not at the right time and place; doing it awkwardly or otherwise not in the manner expected. It may range from a slight to severe deviation in terms of quality or quantity in doing the activity in a manner or to the extent that is expected.\footnote{Beta-1 Draft version of ICIDH-2 (WHO).}

\textit{acuity}: sharpness, acuteness (OED), as in \textit{auditory acuity}.

\textit{acute otitis media}: middle ear infection of relatively sudden onset and of relatively short duration; very common, especially in children.

\textit{ADG}: air defence gun.

\textit{advantage}: the position, state or circumstance of being in advance of another, or having the better of him in any respect (OED).

\textit{AEA}: Association of European Audioprosthesists.

\textit{AEP}: auditory (or, acoustically) evoked potentials.

\textit{AFNOR}: l’Association française de normalisation.


\textit{agnosia, auditory}: inability to recognize music, words or other organized sounds because of a defect of the hearing part of the brain.
AHCP: Army Hearing Conservation Programme (UK).

AIHA: American Industrial Hygiene Association.

*air–bone gap*: the separation between the hearing threshold levels measured by air conduction and by bone conduction audiometry expressed as the degree to which the air conduction HTL exceeds the corresponding bone conduction HTL. Having regard to degrees of uncertainty, the value, if positive, would indicate a conductive (middle ear) impairment of hearing, and, if negative, a non-organic component in the measured threshold of hearing.

*air conduction audiometry*: audiometry, invariably using *earphones*, whereby the test sounds are sent through the normal air conduction pathway of hearing – through the air-containing outer and middle ears. The method is used to determine an individual’s threshold of hearing by air conduction; the results are portrayed graphically as an air conduction audiogram.

ALARA: as low as reasonably achievable (a criterion used in radiation medicine where, for any practice involving radiation, protection should be optimized to take into account economic and social considerations).

ALARP: as low as reasonably practicable (a criterion used in radiation medicine). Although the current statutory occupational radiation dose limit is 50 mSv per annum, the regulations made under the Health and Safety at Work Act stress that all doses, both to occupationally exposed persons and to the general public, should be kept as low as reasonably practicable, where ‘reasonably practicable’ has a financial dimension of ‘gross disproportion’ between cost and the achievable reduction in radiation dose.

*algorithm*: a series of instructions or procedural steps for the solution of a specific problem.\(^{195}\)

*algorithmic approach*: a method of problem-solving by a fixed procedure.

*allocation*: synonymous with *apportionment* (a term used in the USA).

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\(^{195}\) Chandor A (1970).
AMA: American Medical Association – the principal organization representing the medical profession in the USA.

aminoglycosides: a group of antibiotics whose chemical structure is characterized by two or more amino sugars joined by a glycoside linkage (hence the name) to a central hexose. Examples are gentamicin, neomycin, streptomycin; this group of antibiotics is potentially ototoxic.

amplitude: the peak value of a simple sinusoidal quantity.

anacusis: complete elevation of the hearing threshold level – total loss of hearing.

ANC: Association of Noise Consultants.

anhedonia: absence of pleasure from the performance of acts that would ordinarily be pleasurable.

ANOPP: Aircraft Noise Prediction Program.

ANSI: American National Standards Institute (successor to ASA); equivalent in USA to BSI.

antibiotic: a chemical substance derived from a fungus or a bacterium that inhibits the growth of other micro-organisms. For example, penicillin. The aminoglycoside group of antibiotics are potentially ototoxic.

AOM: acute otitis media.

APC: armoured personnel carrier.

apoptosis: biologically programmed cell death (the molecular biological basis of ageing).

apportionment: the portioning out of some dimension (for example hearing threshold level, auditory symptoms, hearing disabilities, handicap, activities, participation, loss of quality of life) to various medical causes (for example ageing processes, occupational noise damage, acoustic trauma, other disease processes), other factors (gender, socio-economic, quantization error, calibration variation, personal equations) and/or time spans. Such information may be required by lawyers to deter-
mine what proportion of a compensable condition can be attributed to the alleged damaging factor *per se*, what proportion occurred during a negligent period, and what proportion could be attributed to one or other defendant (see allocation, attribution). The use of NPL Tables Ac 61 in ONIHL cases was approved by Mr Justice Mustill in *Thompson, Gray and Nicholson v Smiths Ship repairers (North Shields) Ltd; Blacklock and Waggott v Swan Hunter Shipbuilders Ltd; Mitchell v Vickers Armstrong Ltd and the Swan Hunter Shipbuilders Ltd* [1984] 1 All ER 881.

**APRE:** Army Personnel Research Establishment (UK).

**argumentum ad hominem:** an argument that takes advantage of the character or situation of a particular opponent.

**ARHL:** abbreviation for age-related hearing loss (synonymous with AAHL and ARPTS).

**ARPTS:** age-related permanent threshold shift. If this is sufficiently pronounced to produce symptoms it would constitute the clinical condition of *presbyacusis*.

**ART:** acoustic reflex threshold (the sound level, measured as dB HL, that is required to produce reflex contraction of middle ear muscle(s) in response to a sound stimulus).

**artificial ear:** a piece of equipment used to calibrate air conduction audiometers; the device is designed to simulate the physical properties of the average normal adult human ear that are relevant to measuring hearing by earphone listening. The specifications for such a device are given in IEC 318.

**artificial mastoid:** A piece of equipment used to calibrate bone conduction audiometers. Specifically, it is designed to simulate the relevant physical properties of the firm prominence of the adult human head behind the *auricle* for the purpose of calibrating a *bone-vibrator*.

**ASA:** American Standards Association (predecessor to ANSI).

**ASHA:** American Speech-Language-Hearing Association.

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196 Specifically, the *acoustic impedance* of the ear.
Association française de normalisation: the French standardization institute.

ASTMS: Association of Scientific, Technical and Management Staffs (now MSFU).

asymptotic threshold shift: phenomenon whereby a prolonged exposure to noise of from eight hours to several days produces a threshold shift that levels off (becomes asymptotic) – it reaches a plateau that does not increase with additional duration of exposure.

ATI: Annual threshold increase. Rate of progression of a deterioration in hearing threshold level measured in dB per annum (used by Kunst et al., 1998).

ATS: asymptotic threshold shift.

attack rate: see incidence.

attobel: $10^{-18}$ bels.

attrition: synonymous with apportionment (a term used in the USA).

audiogram: a chart that portrays in graphic form the results of audiometry.

audiology: that part of human knowledge and endeavour (educational, medical and scientific) concerned with hearing and its disorders (a word which is sometimes used incorrectly as a synonym for audiometry).

audiometer: an electro-acoustic instrument for the measurement of hearing.

audiometric picture: the constellation of audiometric abnormalities that either characterizes a hearing disorder or characterizes a particular individual’s hearing disorder. For occupational noise damage to hearing there is ‘a characteristic pattern on the audiogram showing typically the greatest loss at the 4,000 Hz frequency’ (DHSS, 1973, paragraph 31).

audiometry: the measurement of hearing using electro-acoustic equipment.

auditory acuity: a term to denote sharpness of hearing; useful to describe
hearing sensitivity without any commitment as to whether or not the hearing is within the range of normality or outside it, and if the latter whether it is better or poorer, and if poorer, whether it amounts to an impairment (material or otherwise) or a hearing loss and whether or not it results in one or more inability, disability or handicap.

**auditory hallucinations**: hearing organized sounds (in contrast to **tinnitus**), such as voices or music, which are not audible to others and where there is no corresponding external stimulus.

**auditory tube**: an alternative term for the **pharyngotympanic tube**.

**auricle**: the flap-like structure on either side of the head, which, being the only visible part of the ear, is generally recognized as ‘the ear’.

**automatic recording audiometer**: a pure-tone audiometer where selecting the ‘loudness’ and pitch of a test tone (signal) is controlled automatically, as is the presentation of the signal, and the recording of the subject’s responses to it.

**A-weighted sound exposure** ($E_{A,T}$): The time integral of the squared A-weighted sound pressure over a specified time period, $T$, or event, expressed in pascal squared seconds (Pa$^2$.s). The period, $T$, measured in seconds, is usually chosen so as to cover a whole day of occupational exposure to noise (usually 8 hours, or 28 800 seconds) (ISO 1999, paragraph 3.3).

**A-weighted sound pressure level** ($L_{pA}$): the sound pressure level, in decibels, determined by using frequency-weighting A (see IEC 651), from the equation.

$$L_{pA} = 10 \log \left( \frac{p_A}{p_0} \right)^2$$

where $p_A$ = A-weighted sound pressure in pascals (ISO 1999, paragraph 3.2).

Frequency-weighting A is designed to give the same frequency response as the human ear at the 40 phon equal loudness contour.

**B duration**: see pressure-envelope duration.

**BAAP**: British Association of Audiological Physicians (the association concerned with advancing the interests of those medical specialists who are concerned with disorders of balance and auditory communication).
**band pressure level:** The sound pressure level $L_{OD}$, $L_{GD}$ or $L_{GF}$ corresponding to the part of the spectrum under measurement. The suffixes indicate the band width and the type of sound field, viz. $O$ for octaves, $G$ for critical bands, $F$ for frontal sound and $D$ for diffuse sound (BS 4198).

**BAOL:** British Association of Otolaryngologists (the association concerned with advancing the interests of British ear, nose and throat specialists).

**BASC:** British Association for Shooting and Conservation (the national representative body in the UK for shooting sports; 114 000 members).

**baseline audiogram:** ‘Within 6 months of an employee’s first exposure at or above the action level, the employer shall establish a valid baseline audiogram against which subsequent audiograms can be compared’ (paragraph (g)(5) of § 19.10.95 Occupational noise exposure (US Department of Labor Occupational Noise Exposure Standard – Code of Federal Regulations, Title 29, Chapter XVII, Part 1910, Subpart G, 36 FR 10466, May 29, 1971; Amended by 48 FR 9776, March 8, 1983)).

**Bayesian statistics:** statistics based upon Bayes’ theorem.

**Bayes’ theorem:** A theorem that provides a numerical expression for the resulting probability of a hypothesis $h$ after the addition of some evidence $e$ to the antecedent body of knowledge $a$. It can be used to force initially diverging (‘subjective’) judgements of probabilities into convergence as evidence comes in, i.e. as one moves from prior to posterior probabilities. Prior probabilities are converted to posterior probabilities by multiplication in proportion to what are termed likelihoods.

**bc:** bone conduction.

**BC:** bone conduction.

**BCS:** (a) British Computer Society; (b) British Calibration Service (an NPL-operated scheme whereby the capability of a calibration laboratory is assessed stringently and, if accepted, the laboratory is given approval to provide a calibration service on a commercial basis).

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197 A Wrexham-based association.

198 OSHA (Occupational Safety and Health Administration) Hearing Conservation Amendment.
BE: behind the ear (of hearing aids).

BEA: \(^{199}\) better ear average (for hearing threshold levels, usually for the frequencies 0.5, 1, 2 and 4 kHz).

Békésy audiometer: \(^{200}\) an automatic recording audiometer that is able to conduct sweep frequency audiometry – to test a subject’s hearing using a continuously variable test tone (glide tone) (used in specialised diagnostic clinics).

BER: brainstem electrical response audiometry.

BERA: brainstem electrical response audiometry.

BFSS: British Field Sports Society. \(^{201}\)

Bias: a systematic tendency in the design of, conduct of, or analysis of the data from a study that results in the association between one or other factor and a condition, such as a disease, being underestimated or overestimated.

Birth cohort: a group of people who were born in a particular year, or years.


BMA: British Medical Association. The principal organization representing the medical profession in the UK.

\(^{199}\) An abbreviation used by the Medical Research Council’s Institute of Hearing Research.

\(^{200}\) Named after its designer, Georg von Békésy (Nobel Prize winner).

\(^{201}\) Inter alia, promotes courses to improve technique and style in sports shooting.
**bone conduction audiometry**: audiometry using a **bone vibrator** in lieu of **earphones** in order to send the test sounds through the solid structures of the head to the cochlea of the internal ear; the aim is to bypass the normal air conduction pathway of hearing so that any obstruction to the passage of sound therein is circumvented. The method is used to determine an individual’s threshold of hearing by bone conduction. The results are portrayed graphically as a bone conduction audiogram (usually on the same chart as the air conduction audiogram).

‘It is tempting to assume if bone conduction is reduced, there must be a corresponding degree of sensorineural hearing loss. However, there are practical pitfalls. Some skulls and the skin and soft tissues over them do not conduct sound as well as others. As another example, when the footplate of the stapes is firmly fixed in the oval window by otosclerosis, the fluids in the inner ear can no longer move so freely under the influence of bone-conducted acoustic energy. This makes the hearing threshold level at 2000 Hz for bone conduction 10 to 15 dB poorer than it would otherwise be’ (Davis, 1978).

**bone vibrator**: the item that is connected by an electrical lead to a sound-generating system (specifically, a hearing aid or an audiometer capable of bone conduction testing) and is placed over one or other bony structure (usually the skull behind the ear) with the purpose of delivering audible stimuli to the inner ear, so bypassing the outer and middle ears.

**BOR**: Branchio-oto-renal syndrome.

**BRAIN**: acronym for Basic Research in Aircraft Internal Noise, a project that is part of the European IMT-EEC programme (http://www.cira.it/reps_en/bra.htm).

**branchio**: relating to gills.

**branchio-oto-renal syndrome**: a congenital and hereditary syndrome characterized in its full expression by development abnormalities relating to our ancestral gills, the ears, and the kidneys.

**Bronstein’s bounce**: a decaying, bobbing up and down of the tracked threshold of hearing which follows the temporary fatiguing effect of exposure to high level sounds. Named after the Russian scientist, Al Bronstein, who first reported the phenomenon in 1936.
BSA: British Society of Audiology (the British multidisciplinary national society of doctors, engineers, scientists and other professionals who are interested in hearing and its disorders).


C: acoustic compliance.

CAA: Civil Aviation Authority.

calibration: a test procedure applied to a piece of equipment to ensure that it conforms to a particular standard.

Carhart notch: notching at, or around, 2 kHz in the bone conduction threshold of hearing in disorders of the middle ear, due to the middle ear pathology affecting the mechanics of hearing by bone conduction, Not to be attributed to damage to the sensorineural mechanism either by the middle-ear disease or by any factor affecting the internal ear or nerve of hearing.

caspase enzymes: cysteine proteases; enzymes that play a crucial role in apoptosis.

catalyst: an inorganic chemical that, when present in small amounts, speeds up a chemical reaction by increasing the rate of approach of the reaction to equilibrium. Catalysts, in contrast to enzymes, are not very specific – they can influence a wide variety of reactions.

CCITT: Comité Consultatif International Télégraphique et Téléphonique. An international committee established to promote standards for the development of telephone, telegraph systems and data networks and to create the environment for interworking between the networks of the different countries of the world. Has now become ITU-T.

CEN: Comité Européen de Normalisation. European Committee for Standardization, which prepares European Standards (ENs) in the three official languages (English, French and German). All national member committees must implement these standards.

CENELEC: Comité Européen de Normalisation Électrotechnique.
CEOAE: click-evoked otoacoustic emissions.

CERA: abbreviation for cortical electrical response audiometry (sometimes written CRA or ERA).

CHABA: abbreviation for Committee on Hearing and Bioacoustics (US).

Chronic suppurative otitis media: longstanding infection of the middle ear that is associated with pus formation. The disease process impairs the sound transmitting function of the middle ear. This manifests as an air–bone gap on audiometry.

CI: confidence interval.

CIRA: (a) Centre for Ionizing Radiation and Acoustics (the Department at NPL that deals, inter alia, with acoustical measurements, calibration and standards); (b) Centro Italiano Ricerche Aerospaziali (the Italian Aerospace Research Centre).

Clinical audiometric picture: the term (Klinisch-audiometrisches Bild) used by some German authorities for what in English speaking countries would be referred to simply as the audiometric picture.

Clinical Outcomes Group: a multi-professional committee that advises the Department of Health on how to improve outcomes of clinical care.

Clinical picture: the constellation of symptoms and physical signs, ignoring the contribution of special diagnostic tests (such as X-rays, blood tests, audiometry), which either characterizes a disorder or characterizes a particular individual’s disorder (clinical picture thus relates to the use of zero-level or low-level technology). Some confusion has been generated by the use of such terms as ‘clinical radiology’, ‘clinical haematology’ and ‘clinical audiometry’, but these terms have evolved to distinguish the use of such tests in an individual health service setting rather than an occupational or public health setting, for example, industrial audiometry and screening audiometry respectively. The clinical picture of occupational noise damage to hearing is non-specific (DHSS, 1973, paragraph 31).

Clinical Standards Board: Scottish equivalent to National Institute of Clinical Excellence.

Clinically undifferentiated: term applied to a case of impaired hearing that is not associated with the visible abnormalities of other parts of the
body that would indicate that the hearing loss is part of a recognizable syndrome.

clinician: a health care professional (medical, scientific or surgical) concerned with the clinical investigation and management of individuals seeking help.

CNEL: community noise-exposure level.\textsuperscript{202}

CNR: community noise rating.

CNS: central nervous system.

c/o: complains of.

COAE: click-evoked otoacoustic emissions.

cochlear labyrinth: the sound sensitive and sound analysing organ of the internal ear; it is affected by a number of genetic disorders, non-genetic disorders, mechanical, blast and noise injuries and ageing processes.

coding: (a) the translation of information, such as responses to a questionnaire, into numbers, or numbered categories, for use in a data processing system; (b) the translation of sensory information into neurophysiological signals for analysis and interpretation, for example, the way in which the stimuli of sound (intensity, frequency) and its location are dealt with by the nervous system.

COG: Clinical Outcomes Group.

cohort: see birth cohort.

cohort study: an epidemiological study which compares one or another feature of people of one birth cohort with the those of another cohort and may involve following up these people over an extended period of time. Same-age older Swedish men from birth cohorts differing only by five years show differences in hearing acuity. It is also implicit in the results of the UK NSH that there are differences in hearing acuity between different birth cohorts, i.e. after allowing for ageing differences.

\textsuperscript{202} Used in the state of California.
**complication:** a disease process\(^{203}\) that occurs during a disease but is not an essential part of the disease, although it may result from it or from an independent cause.

**confidence interval:** ‘the computed interval with a given probability, for example 95%, that the true value of a variable such as a mean, proportion, or rate is contained within that interval’ (Last, 1995).

**confounding factor:** a third factor (measure, variable) that is responsible for an apparent correlation between two variables.

**contextual factors:** factors in the total background to a person’s life and living, including external, environmental factors, and internal, personal factors.\(^{204}\)

**control group:** a group of subjects with whom comparison is made in a case-control study, randomized controlled trial, or other variety of epidemiological study. Selection of appropriate controls is crucial to the validity of epidemiological studies and has been much discussed, e.g. Schlesselman (1982), Wacholder et al. (1992), Last (1995).

**controls, historical:** ‘Persons or patients used for comparison who had the condition or treatment under study at a different time, generally at an earlier period than the study group or cases. Historical controls are often unsatisfactory because other factors affecting the condition may have changed to an unknown extent in the time elapsed’ (Last, 1995). By analogy we also have what might be termed ‘geographical controls’, which again may be unsatisfactory.

**controls, matched:** ‘Controls who are selected so that they are similar to the study group or cases in specific characteristics. Some commonly used matching variables are age, sex, race, and socioeconomic status’ (Last, 1995).

**controls, neighbourhood:** ‘Persons used for comparison who live in the same locality as cases and therefore may resemble cases in environmental and socioeconomic criteria’ (Last, 1995).

\(^{203}\) Stedman’s Medical Dictionary (1995).

\(^{204}\) Beta-1 Draft version of ICIDH-2 (WHO).
correlation: a statistical term to denote the correspondence between two measures.

correlation coefficient: a numerical measure, ranging from zero (indicating no correlation) to one (complete correspondence), of the degree of association between two characteristics, but only when their relationship is adequately described by a straight line.

corrosion: the slow destruction of materials by chemical agents and electrochemical reactions.

cosh: abbreviation for hyperbolic cosine; pronounced as ‘cosh’.

coupler: see acoustic coupler.

CPD: Continuing Professional Development; implements concepts of skill maintenance and improvement.

cps: cycles per second (the old designation for hertz).

CPSA: Clay Pigeon Shooting Association.

CRA: see CERA.

creep failure (of materials): failure of a structure due to slow deformation under prolonged stress.

crest factor: a measure of the ‘peakiness’ of a noise.

critical band: a band of frequencies, centred round a nominal frequency, such that the loudness is equal to that of a narrower band of the same sound pressure level, but less than that of a wider band of the same sound pressure level. Critical bands are approximated by bands one-third of an octave wide above 280 Hz and by groups of one-third octave bands for lower frequencies (BS 4198).

critical level: sound pressure level at which the mode of damage to the cochlea by impact/impulse noise shifts away from metabolic damage to mechanical damage; the critical level depends on the signature of the impulse – its spectrum and duration. The critical level may be anywhere between 115 dB and 155 dB peak SPL.
c/s: cycles per second (the old designation for hertz).

CSOM: chronic suppurative otitis media.

CTE: chronic toxic encephalopathy.

cubic equation: a polynomial equation of the third degree.

cursive threshold: on automatically recorded thresholds of hearing, the mid-point between the peaks and the valleys of the traces.

curve fitting: a statistical technique (or techniques) to find the line or curve that describes best the data under consideration and define the mathematical expression that describes that line or curve. In many cases, knowledge of the science, or sciences, that have a bearing on the subject matter indicates the type of curve that might be appropriate and visual inspection of the plotted data can confirm such a choice.

d': ('dee prime') detectability index. A measure derived from signal detection theory. Receiver operating characteristic (ROC) curves show the probability of a true positive response versus a false positive response for a signal or sound.

daily A-weighted sound exposure (E_{A,D}): the total A-weighted sound exposure sustained in a single 24-hour day (ISO 1999; paragraph 3.4).

damage-risk criterion: level of sound above which it is considered to be hazardous to hearing.

data: any group of numerical values that have been arranged to represent information in accordance with predefined rules.

database: ‘A repository of stored information organized in such a way that data are easily retrieved. Normally associated with an organized base of data stored within a computer that is usable by multiple applications. An everyday example of a non-computer database is the telephone directory’205 (Byers, 1984).

dB: abbreviation for ‘decibel’.

205 But now major telephone companies in the world hold the database for their subscribers on CD-ROM.
**dB(A):** unit for sound level quantities measured with the A frequency weighting on a sound level meter.

**dB (NI):** unit for *noise immission levels.*

**DCIEM:** Defence and Civil Institute of Environmental Medicine (of Canada; located in Toronto).

**Deafness:** total hearing loss.

**Decibel:** the unit used for expressing the physical magnitude of sounds.

**Decibel scale:** a logarithmic ratio scale used to quantify the magnitude of a sound level. As it is a ratio scale there is a reference sound level, so a sound of zero dB will be when the sound level in question is numerically equivalent to the reference zero. Consequently there are many 0 dB levels, depending on the reference level used. It is thus unlike the arithmetically linear scales that are used, for example, to measure length and mass, and where each scale has only one zero value.

**Def': design effect.**

**Derate:** to use a fraction of a hearing protector’s noise reduction rating (NRR) to calculate the noise exposure of a worker wearing that hearing protector.

**DES:** deafness-earpits syndrome.

**Design effect:** (epidemiology) a design-specific statistic of a sample that is the square root of the ratio of the variance obtained for the sample compared with what it would be if the sample had no stratification structure (a random sample). The value may be expressed as a proportion or as a percentage, as in chapters 3 and 4 respectively of Davis (1995). The values reported show that the effect of stratification, which partitions variance within and between particular strata, was successful.

**Design of experiments:** the science of obtaining unambiguous results of the highest possible accuracy from experiments on variable material. A crucial component is randomization, which is directed to the elimination of bias.

**Deterministic damage (effects of radiation):** the acute, clinically detectable effects of radiation exposure (only occur above a dose threshold of 1 Gy).
DETR: (a) Department of the Environment, Transport and the Regions (UK); (b) Department of Employment, Training and Rehabilitation (State of Nevada, USA).

Deutsches Institut für Normung: the German Standardization Institute.

DFU: detailed follow-up (as part of a hearing conservation programme).

DHEW: Department of Health, Education, and Welfare, the US Government Department which embraces NIOSH.

DHHS: Department of Health and Human Services (USA).

DHSS: Department of Health and Social Security (subsequently split into the Department of Health and the Department of Social Security).

DoH: Department of Health.

DSS: Department of Social Security.

diagnostic suspicion bias: bias attributable to knowledge of past or current exposure to a known causative factor suggesting a particular diagnosis.

difference limen: increment (or decrement) in one or other feature of a stimulus (such as sound intensity or frequency) that is just noticeable.

DIN: Deutsches Institut für Normung.

diplacusis: an abnormal perception of sound in respect of time or pitch in which one sound is heard as two sounds.

diplacusis, binaural: a given sound is perceived as two different sounds in the two ears.

diplacusis echoica: a sound heard in the affected ear is perceived as being repeated.

diplacusis, monaural: a sound heard in the affected ear is perceived as two sounds.

206 Now termed the Department of Health and Human Services (DHHS).
**Directive:** an EC measure which is binding ‘as to the results to be achieved, upon each member State to which it is addressed’, but allows states discretion as to the form and method of implementation. Directives are published in the *Official Journal of the European Communities* in the L series. A considerable number have now appeared on environmental noise, beginning with 70/157/EEC which applies to motor vehicles.

**DIS:** Draft International Standard.

**disability:**

(a) ‘In the context of health experience, a disability is any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal’ for a human being . . . Disability represents a departure from the norm in terms of performance of the individual, as opposed to that of the organ or mechanism. To say that someone has a disability is to preserve neutrality.. However, . . . to say that someone is disabled . . . is to risk being dismissive (International Classification of Impairments, Disabilities, and Handicaps: A Manual of Classification Relating to the Consequences of Disease (1980) Geneva: World Health Organization). As regards hearing, it would cover everyday use, as in the ability to converse under different conditions. (b) ‘The term “disability” summarizes a great number of different functional limitations occurring in any population in any country of this world; people may be disabled by physical, intellectual or sensory impairment, medical conditions or mental illness; such impairments, conditions or illness may be permanent or transitory in nature’ (Para 17, UN Standard Rules). (c) ‘[A] person has a disability for the purposes of this Act if he has a physical or mental impairment which has a substantial and long-term adverse effect on his ability to carry out normal day-to-day activities.’

**disabled person:** a person who has a disability.

**disablement:** (a) an umbrella medical/sociological term to cover all the negative dimensions of the ICIDH (impairments, activity limitations and participation restrictions – formerly referred to disabilities and handicaps), either together or separately. There is a need for a general superordinate term to indicate all the dimensions together; although the term ‘disablement(s)’ may not be ideal, no better word has been found;

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207 The term is now deprecated and not used in ICIDH-2.
208 Our italics; some proposals to assess disability quantitatively ignore this criterion.
in the singular the term can indicate ‘the process of’ or ‘an act of’ disabbling someone; however in its plural form it is used exclusively as a replacement term to indicate impairments, activity limitations and participation restrictions;\(^\text{211}\) (b) a legal term that was used in the National Insurance (Industrial Injuries) Act 1965. The Act did not define the term but ‘clarification has been given in the courts from time to time. In the case of Hudson, which reached the House of Lords [1972] 2 WLR 210 at 265. Loss of faculty was interpreted as impairment of the proper functioning of part of the body or mind, disability as partial or total failure of power to perform normal bodily or mental processes and disablement as the sum of disabilities which when compared with the powers of a normal person can be expressed as a percentage’.\(^\text{212}\)

**disablement benefit**: a legal term that defines that which is payable under (initially) the National Insurance (Industrial Injuries) Act 1965 when, as a result of an industrial accident or a prescribed disease, an insured person suffers from a loss of physical or mental faculty that results in disablement amounting to not less than 1%.\(^\text{213}\)

**disabling hearing impairment**: (a) in adults should be defined as a permanent unaided hearing threshold level of 41 dB or greater; (b) in children under the age of 15 years it should be defined as a permanent unaided hearing threshold level for the better ear of 31 dB or greater. For both children and adults the ‘hearing threshold level’ is to be taken as the better ear average hearing threshold level for the four frequencies: 0.5, 1, 2 and 4 kHz (Conclusions and Recommendations of First Informal Consultation on Future Programme Developments for the Prevention of Deafness and Hearing Impairment. Geneva: WHO, January 1997.

**disadvantage**: absence or deprivation of advantage; an unfavourable condition or circumstance.

**dispersion**: the spread of values obtained from a particular measurement.

**DL**: difference limen.

\(^{211}\) Beta-1 Draft version of ICIDH-2 (WHO).

\(^{212}\) Department of Health and Social Security (1974).

\(^{213}\) Department of Health and Social Security (1974).
**DLR**: Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V. (the German Aerospace Research Establishment).

**DPOAE**: distortion product otoacoustic emissions (otoacoustic emissions recorded in response to two simultaneous primary tones, $f_1$ and $f_2$).

**DRC**: see *damage-risk criterion*.

**dys-**: a prefix that denotes difficult or bad.

**dysacusis**: a term that has been applied to any impairment of hearing that is not primarily a loss of auditory sensitivity, so that it has been used to cover the *diploacusises, dysstereoacusis, hyperacusis, speech discrimination loss, auditory agnosia*.

**dysstereoacusis**: impaired ability in the spatial localisation of sound (see *paracusis loci*).

**$e$**: (a) base of natural logarithms (2.71828 . . .); (b) (or $\varepsilon$) error term, for example as used by the Medical Research Council’s Institute of Hearing Research in its first age/noise equation.

**$E$**: total energy.

$E_N$: symbol for *A-weighted noise immission level* (Burns and Robinson, 1970; appendix 2).

$E_{A,D}$: symbol for *daily A-weighted sound exposure* (ISO 1999; paragraph 3.4).

$E_{A,T}$: symbol for *A-weighted sound exposure* (ISO 1999; paragraph 3.3).

**ear canal**: a colloquial term for the *external acoustic meatus*.

**earphone**: an electro-acoustic device that converts electrical signals into sound signals and that is placed on (or in) an ear in order to deliver sound (for example from a hearing aid or an audiometer) through the *outer ear passage* and middle ear to the *inner ear*.

**earpit**: a minute pit that is present from birth in the skin covering the auricle (typically on the anterior border of the ascending limb of the *helix*, and so referred to as being *anterior helicine*), or, less commonly, on the
face in front of that structure (and so referred to as being *pre-auricular*).\textsuperscript{214} May be associated with a hearing loss of variable type, i.e. part of branchio-oto-renal syndrome.

*earpits-deafness syndrome*: a condition characterized by the association of earpits and a hearing loss. Now redefined under the umbrella of branchio-oto-renal syndrome.

*EBM*: evidence-based medicine.

*EC*: European Community/Communities (successor of EEC).

*EEC*: European Economic Community (succeeded by EC).

*EFAS*: European Federation of Audiology Societies.


*EL*: echo level.

$E_{\text{Aeq}}$: estimated $L_{\text{Aeq}}$

*emission*: that which is emitted, for example as used by the European Commission in its Green Paper on Future Noise Policy: ‘The Commission will investigate the feasibility of introducing legislation setting emission limit values’, and by the various standards institutions, for example ‘BS EN ISO 11203: 1996 Acoustics. Noise emitted by machinery and equipment. Determination of emission sound pressure levels’.

*EN*: Euronorm (European Standard; Norme Européenne; Europäische Norm). Mandatory for all participating countries. When the standards of the International Electrotechnical Commission are adopted, the value ‘60 000’ is added to the IEC number, for example IEC 645-1 becomes EN 60645-1, and when those of the International Organization for Standardization are adopted, the value ‘20 000’ is added to the ISO number, for example ISO 7566 becomes EN 27566.

*environmental factors*: the background of a person’s life and living, composed of components of the natural environment (weather or

\textsuperscript{214} Unfortunately, the typical helicine earpit is now often described as a *pre-auricular sinus*, when, in fact, it is an *auricular sinus*.
terrain), the human-made environment (tools, furnishing, the built-environment), social attitudes, customs, rules, practices and institutions, and other individuals.215

**enzyme**: protein *catalysts* that exist in living tissue. They show a high degree of specificity – they usually speed up only one chemical reaction, or a few related reactions. The name of an enzyme usually denotes the *substrate* on which it acts with the ending ‘-ase’ denoting that the substance is an enzyme, for example the *caspase* enzymes.

**EOAE**: evoked otoacoustic emissions (Kemp ‘echoes’); may be click-evoked otoacoustic emissions or distortion product otoacoustic emissions.

**EPA**: Environmental Protection Agency (USA).

**epidemiology**: ‘[t]he study of the distribution and determinants of health-related states and events in populations, and the application of this study to control of health problems.’216

**equivalent continuous sound level**: the level of continuous sound in dB(A), which in the course of a working day would cause the same sound energy to be received as that due to the actual sound over a typical day (abbreviation $L_{eq}$).217

**erosion**: the slow destruction of materials by mechanical agents.

**ETSI**: European Telecommunications Standards Institute. Produces telecommunications standards that are needed for European Union legislation.

**EU**: European Union.

**EUFOS**: European Federation of Otolaryngological Societies.

**Eustachian tube**: Eponym for the *pharyngotympanic tube*.

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215 Beta-1 Draft version of ICIDH-2 (WHO).
217 Martin (1976).
Evidence-based medicine: Evidence-based medicine de-emphasizes intuition, unsystematic clinical experience (it is this that distinguishes the clinical opinion *per se* to which Popper (1972) objected and the clinical opinion that is sought in modern evidence-based medicine) and pathophysiologic rationale as sufficient grounds for clinical decision making and stresses the examination of evidence from clinical research. Evidence-based medicine requires new skills from the physician, including efficient literature searching . . . We will refer to this process as the *critical appraisal exercise* (Evidence-Based Medicine Working Group, 1992).

Expected value (or ‘expectation’): an expression used in statistical work to indicate the mean that would occur among some group on the basis of a given hypothesis.  For example, we might look at the mean HTLs of a group of noise-exposed (or not exposed) plaintiffs to see whether this matches the MRC ageing/noise model of hearing.

Experiment: an intentional and reproducible manipulation of a set of factors in order to determine the effect of one or more factor(s) uncontaminated by other factors; the *design of experiments* is now a major branch of statistics, For ethical and other reasons the scope of experimentation on man is limited. One cannot randomly allocate people of different socio-economic groups to jobs of prescribed noise levels and require them to smoke prescribed numbers of cigarettes per day or consume prescribed amounts of alcohol per week. Assessments of the relative importance of these factors must therefore be dependent on *sub-experimental studies* (including surveys). Because of the problem of variability with biological material together with the operation of selection processes, experimental studies in physiology and medicine typically take the form of what have been termed *randomized controlled trials*.

Experimental design: see *design of experiments*.

External acoustic meatus: the air-containing channel that connects the auricle to the middle ear.

\( f \): symbol for Deft.

\( f \): (a) symbol for frequency; (b) instantaneous force.

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\(^{218}\) Hill and Hill (1991, at p. 66).
**Fabrique Nationale**: the Belgium company that manufactures weapons that bear the prefix ‘FN’.

**factor analysis**: a method of *multivariate analysis* whereby the performance of the subject on a large number of tests can be examined for the presence or absence of common factors.

**Fast Fourier Transform**: a technique of quickly converting a time signal into its frequency spectrum.

**FAQ**: Frequently asked questions.

**fatigue (of materials)**: repeated application of stress below the proportional limit that leads to *fracture*, which application if applied once only would not cause failure of the structure.

**fence**: a hearing threshold level above which degrees of hearing disability, handicap are deemed to exist.

**FFT**: Fast Fourier Transform (an abbreviation that is used on ‘echo’ reports). It expresses the results of translating (by a quick procedure) a signal\(^{220}\) from the time domain to the frequency domain.

**FN**: Fabrique Nationale.

**fractile**: the value of the item which is a given fraction of the way through a statistical distribution.

**fracture (of materials)**: a failure that propagates, often rapidly, from one side to the other side of a structure.

**frequency**: an attribute of a periodic quantity being the repetition rate of the cycles. The unit is the hertz (abbreviation Hz).

**frequency coding abnormalities**: abnormalities in *frequency* perception resulting from the way in which the affected ear(s) translate(s) the

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\(^{219}\) Baron Jean Baptiste Joseph Fourier (1768–1830), a French mathematician who showed how a time signal could be transformed into its frequency components (spectral analysis).

\(^{220}\) In this case, the ‘echo’. 
frequency information in a sound stimulus to nerve impulses, for example, the diplacuses.

*fricative:* those sounds, such as f, s and z, which are made by the friction of breath through a narrow opening of the vocal tract.

*function:* (a) the work a thing is assigned to do; official duty; public ceremony or occasion (OED); (b) the expression in mathematical symbols of the relationship between *variables.* Thus if $x$ and $y$ represent real numbers, then $y$ is a function of $x$ if $y$ is uniquely determined by the value of $x$. For example, the equation.

$$y = 6x$$

states that $y$ is a function of $x$, because for every real number substituted for $x$, there can be only one real number for the value of $y$. Thus if $x = 1$, then $y = 6$; if $x = -2.5$, then $y = -15$.

The above is termed a linear function. Other functions include *logarithmic, power* and *Gompertz functions.*

**FV432:** Fighting Vehicle 432, the British equivalent of the US M113 tracked APC.

**Gaussian distribution:** a particular pattern of distribution of the magnitude of a continuously variable quantity; when represented graphically the distribution exhibits a typical bell-shaped curve, which is defined by a specific mathematical equation.

*gender:* a term used by some authorities, such as the Statistics Division of the UN Department of Economic and Social Affairs, for *sex.* However others would consider this a *genteelism.* ‘When gender replaces the semantically correct word sex – for instances in the headings of statistical tables – it is bewildering to readers whose first language has nouns that may carry any of three genders that are not necessarily related to the sex of the individual (for example, German: *das Mädschen,* the girl.’ (Last, 1995).

*gene:* a biological hereditary unit
**Generalized Linear Interactive Modelling**: a highly respected method for the analysis of complex biological, medical and sociological data.\(^{221}\) It has the backing of the Economic and Social Research Council and the Royal Statistical Society. The technique was introduced in 1972\(^{222}\) and so was not available for either the first Medical Research Council Survey of Hearing or the Medical Research Council/National Physical Laboratory Survey of Hearing and Noise in Industry. This statistical method was used to analyse the National Study of Hearing data.

**gentamicin**: an antibiotic belonging to the aminoglycoside group.

**Gentisone HC ear drops**: a proprietary product used to treat infections of the ear; contains an antibiotic, gentamicin, and an anti-inflammatory agent, hydrocortisone. *Contra-indications*: The topical application of gentamicin as with other aminoglycosides in chronic suppurative otitis media carries a theoretical risk of causing a decrease in hearing perception; however the benefits of treating with gentamicin should be weighed against the risk of chronic infection itself causing hearing loss’ (ABPI Data Sheet Compendium, 1994–5 at pp. 1300–1).

**Gestalt psychology**: considers that we perceive things as wholes. For example, in perceiving a melody, the melodic form derives not from perceiving a string of notes, but from perceiving the unitary whole, which is something more than a collection of the melody’s component parts.

**G-factor complex**: a term used at the 1995 International Advanced Research Workshop on Man and Environmental Noise to cover the various factors affecting hearing threshold levels which are subsumed under the term gender or sex factor; the term serves to emphasize the multifactorial nature of such a factor.

**GLIM**: Generalized Linear Interactive Modelling.

**GMB**: General Municipal Boilermakers and Allied Trades Union.

**GMC**: General Medical Council.

\(^{221}\) McCullagh and Nelder (1983); Healy (1988); Aitkin et al. (1989).

\(^{222}\) Nelder and Wedderburn (1972).
Gompertz function: A function that is defined by the expression:

\[ Y = Vg b^x \]

where \( x \) = independent variable\(^{223} \)
\( Y \) = dependent variable
\( V \) = limiting value of \( Y \)
\( g \) = a constant
\( b \) = a constant

which is the same as

\[ \log (\log Y - \log V) = b \log g \]

i.e. \( \log (\log Y - \log V) = x \log b + \log \log g \)

Therefore data that exhibit a Gompertz function conform to a straight line when the logarithm of the difference between the logarithms of \( Y \) and of \( V \) are plotted against \( x \). The slope of the line is the logarithm of \( b \) and the intercept is the logarithm of the logarithm of \( g \).

GPMG: General Purpose Machine Gun, for example, the 7.62 mm FN MAG GPMG.

Graph: a pictorial representation of data. In the commoner type of graph, a given point (or point on a line) on the graph shows the magnitude for some measurement that has been made (dependent variable) of an object or condition with the corresponding magnitude of some other measurement that has been made (independent variable). The position of each point on the graph is thus determined by the magnitude of each of the two variables. The actual positioning of each point is governed by the scales on each of two lines (the horizontal and vertical axes, which are used to represent the independent and the dependent variable respectively) that lie at right angles to one another in the form, usually, of a large capital ‘L’. An audiogram\(^{224} \) shows the magnitude of the sound pressure level needed for it to be heard by a given individual for a given magnitude of the frequency of the sound; a sound spectrum shows the magnitude of the sound pressure level for a given magnitude of the frequency of a specified sound, or, what is more likely, the centre frequency for a band of frequencies.

\(^{223}\) If time is the independent variable, as is usually the case, one takes the elapsed time from a specified origin.
\(^{224}\) Hence it was formerly known as an ‘audiograph’.
Gray: a special name in radiation medicine for joules per kilogram (for the measurement of absorbed dose).

guideline: ‘A formal statement about a defined task or function. Examples include clinical practice guidelines, guidelines for the application of preventive screening procedures, and guidelines for the ethical conduct of epidemiologic practice and research’ (McDonald and Overhage, 1994).

guidelines, clinical: ‘systematically developed statements which assist clinicians and patients in making decisions about appropriate treatment for specific conditions . . . Clinical guidelines are produced for one reason, and for one reason only: to improve the quality of care’ (National Health Service Executive, 1996 at pp. 4, 7).

Gy: symbol for Gray.

H: when coupled with a digit indicates one of the five grades of hearing for the British Army, for example H1 (good), H2 (acceptable for service purposes), H3 (impaired; probably unfit for entry), H4 (very poor hearing; below entry standard) and H8 (hearing so bad that invaliding out required).

H': abbreviation for hearing threshold level associated with age and noise (HTLAN).

HA: hearing aid.

hallucinations, auditory: hearing organized sounds (in contrast to tinnitus), such as voices or music, which are not audible to others and where there is no corresponding external stimulus.

handicap: (a) ‘In the context of health experience, a handicap is a disadvantage for a given individual, resulting from an impairment or a disability, that limits or prevents the fulfilment of a role225 that is normal (depending on age, sex, and social and cultural factors) for that individual . . . It is thus a social phenomenon, representing the social and environmental consequences for the individual stemming from the presence of impairments and disabilities’ (International Classification of Impairments, Disabilities, and Handicaps: A Manual of Classification Relating to the

225 The term ‘role’ is now deprecated in ICIDH-2.
As regards hearing, it covers the non-auditory consequences of hearing impairment, for example, economic, psychological, social.\textsuperscript{226} (b) ‘The term “handicap” means a loss or limitation of opportunities to take part in the life of the community on an equal level with others. It describes the encounter between a person with a disability and the environment. The purpose of this term is to emphasize the focus on the shortcomings in the environment and in many organized activities in society, for example, information, communication and education, which prevent persons with disabilities from participating on equal terms’ (Paragraph 18, UN Standard Rules).

\textit{HAVS:} hand–arm vibration syndrome (previously known as VWF).

\textit{Hawthorne effect:} improvement in working efficiency that is attributable to social and psychological factors that are incidental to the physical condition(s) being studied. Named after Western Electric’s factory in the US where the effect was discovered (see Mayo, 1933).

\textit{HCC:} (a) Hearing Conservation Council (UK) – a charity established in 1999 for ‘the relief of persons with hearing impairment and deafness and the preservation and protection of health in the United Kingdom and in any country of the world by promoting activities for the prevention, mitigation or relief of avoidable causes of hearing impairment and deafness and for the conservation of hearing’; (b) Hearing Conservation Center (United States Air Force).

\textit{HCDC:} Hearing Conservation Diagnostic Center (United States Air Force).

\textit{HCP:} Hearing Conservation Program.

\textit{health condition:} an alteration or attribute of the health status of an individual which may lead to distress, interference with daily activities, or contact with health services. It may be a disease (acute or chronic), disorder, injury or trauma, or reflect other health-related states such as pregnancy, ageing, stress, congenital anomaly, or genetic predisposition.\textsuperscript{227}

\textit{health status:} state of health.

\textsuperscript{226} These are difficult concepts. Even ISO 1999: 1990 confuses ‘handicap’ and ‘disability’ (at p. 3).

\textsuperscript{227} Beta-1 Draft version of ICIDH-2 (WHO).
**hearing level (HL):** for a specified frequency of pure-tone and testing system, the sound pressure level\(^{228}\) (in the case of air conduction audiometers) or vibratory force level\(^{229}\) (in the case of bone conduction audiometers) of the tone relative to that of a reference zero.\(^{230}\) It is the dial setting of an audiometer if the instrument has been properly calibrated. Expressed in decibels, as dB HL.

**hearing loss:** an impairment of hearing that exceeds a criterial level. It has no units, but may be qualified, in terms of severity, as ‘mild’, ‘severe’ and so forth. Neither the term ‘hearing loss’ nor the term ‘hearing gain’ should be used to describe hearing, which is, respectively, greater than, or less than, the average hearing threshold level, just as the terms ‘height loss’ or ‘height gain’ would not be used to describe the height of someone who was less than, or greater than average height unless it had been shown that a loss or a gain in height had occurred, for example by serial measurements.

**hearing status:** a description of the degree to which the hearing of an individual functions normally with respect to accepted criteria (analogous to health status).

**hearing threshold level (HTL):** for a particular ear, and a given frequency and test system, it is an individual’s threshold of hearing\(^{231}\) as determined in a stated manner and expressed by the system’s indicated ‘hearing level’ value. Expressed in decibels as dB HTL.

**hearing threshold shift:** the change in the threshold of hearing for a given frequency (or group of frequencies) over a particular period of time; expressed in decibels.

**helicine:** pertaining to the helix of the ear.

**HELINOISE:** acronym for Helicopter External Noise, a specific programme directed towards the reduction of noise outside helicopters that has been generated by the machine (in contrast to the RHINO programme).

**helix:** the curved prominent rim of the *auricle*.

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\(^{228}\) Essentially the physical magnitude of the sound.

\(^{229}\) Essentially the physical magnitude of the vibration.

\(^{230}\) As defined by an International or National Standard

\(^{231}\) The quietest sound that he or she can hear.
hertz: unit of frequency (formerly cycles per second).

heterogeneity: multiple causes resulting in the same effect.

heuristic: appealing to an intuitive sense of plausibility (in contrast to rigorous).

heuristic approach: an exploratory approach to a problem which uses successive evaluations of trial and error to arrive at a final result (in contrast to algorithmic approach).233

heuristic program: a program that solves a problem by a method of trial and error in which the success of each attempt at solution is assessed and used to improve the subsequent attempts until a solution acceptable within defined limits is reached.

heuristics: the methodology of solving a problem by trial and error, evaluating each step towards a final result. More specifically, it can be defined as a selective search process used to exploit what one knows about a problem to maximize finding a solution. For example, if someone loses a set of keys, he does not search everywhere but looks in places in which the set might conceivably be (including the lock, or locks, or wherever the set of keys is kept or carried).

HI: Hearing International.

HL: abbreviation for hearing level.

HMG: heavy machine gun.

HMSO: Her Majesty’s Stationery Office.

homeostasis: a physiological mechanism that promotes a return towards conditions from which they were displaced.234

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232 It is important for the word to be in small case as ‘Hertz’ (beginning with an initial capital letter) refers either to the man, Heinrich Hertz (1857–94), a German physicist, after whom the unit is named, or the car hire firm.


234 A concept of the nineteenth-century French medical scientist, Claude Bernard, but actual word attributed to American physiologist, Cannon.
**HPD:** hearing protective device – a hearing protector.

**HSC:** Health and Safety Commission.

**HSE:** Health and Safety Executive.

**HSW Act:** Health and Safety at Work Act 1974.

**HT:** synonymous with hearing threshold level.

**5-HT:** abbreviation for 5-hydroxytryptamine.

**HTL:** abbreviation for hearing threshold level.


**HTLAN:** abbreviation for hearing threshold level associated with age and noise. The value is a combination of the components associated with noise (NIPTS) and with age (HTLA) (paragraph 3.11 of ISO 1999: 1990).

**html:** hypertext markup language.

**http:** hypertext transfer protocol (protocol used on the World Wide Web).

**5-hydroxytryptamine:** serotonin.

**hyperacusis:** abnormal sensitivity to one or other sound.

**hyperbolic cosine:** (abbreviation \( \cosh \)) is defined by the expression

\[
\cosh x = \frac{1}{2} (e^x + e^{-x}).
\]

**hyperbolic sine:** (abbreviation \( \sinh \)) is defined by the expression

\[
\sinh x = \frac{1}{2} (e^x - e^{-x}).
\]

**hyperbolic tangent:** (abbreviation \( \tanh \)) of a number is defined as the ratio of the hyperbolic sine of that number to the hyperbolic cosine of that number

\[
i.e. \quad \tanh x = (\sinh x)/(\cosh x).
\]
used by Robinson and Cook (1968) as the mathematical function relating the noise exposure measures and the noise induced permanent threshold shift; the function therefore appears in NPL Tables Ac 61.

**hypermedia**: the technology which can handle texts, graphics and sounds and on which the operation of the World Wide Web is based.

**hypertext**: that part of hypermedia technology which can handle text.

**hypoacusis**: partial impairment of hearing.

**Hz**: abbreviation for hertz.

**I**: time-averaged *acoustic intensity*.

**I<sub>i</sub>**: instantaneous *acoustic intensity*.

**I<sub>0</sub>**: symbol for the reference acoustic intensity when 10<sup>−12</sup> watts per square metre.

**I<sub>ref</sub>**: symbol for the reference acoustic intensity.

**IAPA**: International Association of Physicians in Audiology (the international association of medical men and women whose particular interest is the investigation and care of individuals with disorders of hearing and/or of balance).<sup>235</sup>


**ICRP**: International Commission on Radiological Protection.

**identity**: An equality such as \( x^2 - 4 = (x - 2) (x + 2) \), which is true for all real values of \( x \), is called an ‘identity’ and written:

\[ x^2 - 4 = (x - 2) (x + 2) \]

**IEC**: International Electrotechnical Commission, the international body that deals with setting standards in the field of electrical technology; based in Geneva. Web site: [http://www.iec.ch/](http://www.iec.ch/).

<sup>235</sup> Also the acronym for the International Airline Passengers Association as well as Instituto de Analisis de Politica Agraria (Institute of Agricultural Policy, Peru).
**IFHOH**: International Federation of Hard of Hearing People.

**IHR**: Institute of Hearing Research (the MRC unit for research on hearing; epidemiology forms a strong component in its research programme).

**IIAC**: Industrial Injuries Advisory Council.

**IL**: intensity level.

**ILO**: (1) International Labour Organization; (b) Institute of Laryngology and Otology, Royal Free and University College Medical School, University College, London University (the principal UK postgraduate medical school for teaching and research in ear, nose and throat diseases and disorders of hearing).

**immission**: that which is immitted – inserted, let in, for example as in noise immission.

**IMPACT**: International Initiative Against Avoidable Disablement (promoted by UNDP, UNICEF and WHO); co-ordinates a global campaign against avoidable disabilities (all, not only those related to hearing). Closely linked with WHO (HQ is in WHO, Geneva).

**impact noise**: the sort of noise that is generated by metal-to-metal impacts in industrial situations; in these instances there may be a less steep shock front or no shock front, but the impact is followed by a substantial amount of reverberant sound.

**impairment**: (a) ‘In the context of health experience, an impairment is any loss or abnormality of psychological, physiological, or anatomical structure or function. Thus the term is more inclusive than “disorder”. For example, the loss of a leg is an impairment but not a disorder’. Assessments of hearing in individual ears relate to impairment. A 1991 editorial in *Audiology* (the journal of the International Society of

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236 Said to be the acronym for *l’Intervention mondial pour l’action contre des traumatismes*, but also the acronym for ‘inventory management program and control technique’ as well as the name for a firm in Kansas City, Missouri, which specializes in industrial hearing conservation programmes.

Audiology) pointed out that there is a continuum of hearing tests ranging from simple pure-tone audiometry to the more complex tests of speech recognition in noise. (b) An impairment indicates a loss or abnormality of a body part (i.e. structure) or body function (i.e. physiological function). The physiological functions include mental functions. Abnormality, here, is strictly used as referring to a significant variation from established statistical norms and should be used only in this sense (as a deviation from a population mean within measured standard norms). Impairments represent a deviation from some ‘norm’ in the biomedical status of the body and its functions, and definition of its constituents is undertaken primarily by those qualified to judge physical and mental functioning according to generally accepted standards. Impairments are classified in categories using defined identification criteria. They are assessed by applying threshold levels and conceptualized as present or absent. Once an impairment is present, it may be scaled in terms of its severity. It should be noted that impairments are not the same as the underlying pathology but are the manifestations of that pathology.239

*impairment index:* an index derived from pure-tone hearing threshold levels as a surrogate for disability or handicap for use in statutory compensation schemes (*Clinical Audiology Course Notes*, Institute of Sound and Vibration Research, 1986, at p. 168).

*impulsive noise:* ‘a short-duration sound, particularly characterised by a shock-front pressure waveform. Such a noise has a very short rise time and is usually generated by an explosion or the blast from a gun’ (Tempest, 1985, p. 55).

*IMT:* Industrial and Material Technologies Programme (of EU).

*inacuity:* a new word which fills the need for a term to denote the complement of *acuity*.

*incidence:* the number of new cases of a condition in a population over a stipulated time period.

*information:* items of *knowledge*.

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239 Beta-1 Draft of ICIDH-2.
infrasound: sound composed of frequencies below the audible range.

INIPTS: industrial noise-induced permanent threshold shift.

inner ear: a colloquial term for the internal ear.

instruction: that part of a computer program that tells the computer what function to perform at that stage.

intensity, acoustic: the measure of the acoustic energy carried through a surface by sound waves (watts per square metre); symbol $I$.

intensity coding abnormalities: abnormalities in loudness perception resulting from the way in which the affected ear(s) translates intensity information in a sound stimulus to nerve impulses, e.g. over-recruitment of loudness.

intensity level: ten times the logarithm of the ratio of the acoustic intensity in question to the reference acoustic intensity (symbol $L_I$).

intermittent noise exposure: noise exposures characterized by short breaks (a few seconds to an hour).240

internal ear: that part of the ear that contains the vestibulocochlear organ.

International Noise Awareness Day: took place on 21 April 1999; announcement made in an article in Hearing International;241 the article was illustrated by a helicopter in flight.

International Organization for Standardization: the international body including standards groups from many countries that develop standards for goods and services to facilitate international trade and exchange. Web site: http://www.iso.ch/.

International Society of Audiology: the international multidisciplinary society concerned with disseminating knowledge of hearing and its disorders.

interquartile distance (or range): the distance between the lower and the upper quartile.

interrupted noise exposure: an exposure that involves long periods of effective quiet (several hours),\textsuperscript{242} for example, the ordinary working schedule.

IoA: Institute of Acoustics (UK).

ISA: International Society of Audiology; International Seabed Authority; Industry Standard Architecture; Individual Savings Accounts (the successor to PEP).


ISVR: Institute of Sound and Vibration Research, University of Southampton (a prestigious centre for research into the effects of sound and vibration, including the effects on man).

IT: Information technology.

ITU: International Telecommunications Union (a Special Agency of the UN).

ITU-T: ITU Telecommunications Standardization Sector (formerly CCITT).

jnd: just noticeable difference (synonymous with DL).

KKS: King–Kopetzky syndrome.

knowledge: the corpus of what is known about a subject.

$L$: symbol for (a) a sound pressure level measured in decibels; (b) inductance.

$L_A$: symbol for a sound pressure level measured on the A-weighting scale of a sound level meter (in dB re 20 $\mu$Pa).

$L_{\text{Aeq}}$: equivalent continuous A-weighted sound pressure level (in dB re 20 $\mu$Pa).

\textsuperscript{242} Nadler (1998).
\( L_{\text{Aeq,T}} \): equivalent continuous A-weighted sound pressure level (in dB re 20 µPa) over a time period, \( T \) (ISO 1999; paragraph 3.5).

\( L_{\text{Aeq,8}} \): equivalent continuous A-weighted sound pressure level (in dB re 20 µPa) for an eight-hour day; it is numerically the same as \( L_{\text{EX,8h}} \).

\( L_{\text{dn}} \): symbol for a measure of sound level that takes into account the influence of the time of day (day/night) on the disturbing effect of environmental noises (concept developed by the EPA).

\( L_{\text{EQD}} \): daily personal noise exposure level (A-weighted) (in dB re \( 11.5 \times 10^{-6} \) Pa\(^2\).s).

\( L_{\text{eq}} \): equivalent-continuous sound level.

\( L_{\text{EX,T}} \): personal noise exposure level (A-weighted) (in dB re \( 11.5 \times 10^{-6} \) Pa\(^2\).s) for a day of duration \( T \) hours.

\( L_{\text{EX,8h}} \): personal noise exposure level (A-weighted) (in dB re \( 11.5 \times 10^{-6} \) Pa\(^2\).s) normalized to a nominal eight-hour working day (ISO 1999 paragraph 3.6). It is numerically the same as \( L_{\text{Aeq,8}} \).

\( L_N \): loudness level.

\( L_p \): symbol for a sound pressure level; the level, in decibels, is given by the equation:

\[
L_p = 10 \lg \left( \frac{p}{p_0} \right)^2
\]

where \( p \) = sound pressure in pascals and \( p_0 \) = reference sound pressure (20 µPa) (ISO 1999 paragraph 3.1).

\( L_{pA} \): A-weighted sound pressure level.

labelling: all the consequences, medical and social, which occur when an individual is informed, rightly or wrongly, that he has some disease or other body abnormality.\(^{243}\)

\( LDL \): loudness discomfort level (but since there are many loudness discomfort levels, it is preferable to refer to the threshold of uncomfortable loudness (TUL), which the LDL test purports to determine).

\(^{243}\) Haynes et al. (1978).
level above threshold: the pressure level of the sound in decibels above its threshold of audibility for the frequency and the individual in question.

L-factor complex: a term used at the 1995 International Advanced Research Workshop on Man and Environmental Noise to cover the various factors affecting hearing threshold levels that are subsumed under the term ‘socio-economic factor’;\textsuperscript{244} the term serves to emphasize the multifactorial nature of such a factor and avoids implicating any strictly ‘social’ or ‘economic’ factor.\textsuperscript{245}

\( lg \): abbreviation for common (Briggsian) logarithms – to the base 10.

linear function: a function that is defined by the expression: \( y = ax + b \) where \( x \) is the independent variable, \( y \) is the dependent variable, and \( a \) and \( b \) are constants. More specifically, \( a \) is the slope, or gradient, and \( b \) is the intercept.

LMLB: Light Mortar Long Barrel, for example the Hotchkiss–Brandt 81 mm LMLB.

\( ln \): abbreviation for natural (Napierian) logarithms – to the base \( e \) (2.71828).

\( \log \): see \( lg \).

logarithm: of a number, \( x \), to a given base, \( b \), is the power, \( n \), to which the base must be raised to equal that number i.e. \( n = \log_b x \), which is the same as \( x = b^n \).

The logarithm of a number \( x \) to base 10 is called a common (or Briggsian) logarithm. The logarithm of a number \( x \) to base \( e \) is called a natural (or Naperian) logarithm.

logarithmic function: a function that is defined by the expression: \( y = a \log_b x + c \),

where \( x \) is the independent variable, \( y \) is the dependent variable, \( a \) is a coefficient of the log term (of \( \log_b x \)), \( c \) is a constant, \( b \) = base of logarithms.

loudness: the subjective dimension of the objective (physical) dimension of sound (intensity, pressure); unit is the sone; as a rule of thumb, a 1-dB

\textsuperscript{244} hence \( L(\text{ibra}) \) – factor.

\textsuperscript{245} How to be precise but vague.
increase in the sound pressure level of a noise gives a 10% increase in loudness, a 10-dB increase produces a doubling of the loudness.

*loudness adaptation*: decrease in the loudness of a steady tone over time.

*loudness level*: the loudness level, in phons, of a sound is numerically equal to the sound pressure level in decibels (relative to a pressure of 20 µPa) of a simple tone of frequency 1 kHz, which is judged by the median listener to be equivalent in loudness (BS 4198).

*loudness recruitment*: the growth of the sensation of loudness more rapidly than is normally the case.

*lower quartile*: the value below which one quarter of the ordered observations fall.

*low fence*: ‘The lowest value of an impairment index that amounts to disability. It is a reasonably well defined concept; below this disability can be presumed not to arise’ (Robinson et al., 1984).

*m*: symbol for (a) metre; (b) mass.

*MAG*: mitrailleuse à gaz (French gas-operated machine gun), for example the 7.62 mm FN MAG GPMG.

*manual audiometer*: a pure tone audiometer where selecting the ‘loudness’ and pitch of a test tone (signal) is done manually, as is the presentation of the signal, and the recording of the subject’s responses to it.

*mastoid process*: the bony prominence of the skull that underlies the mastoid prominence.

*mastoid prominence*: the firm projection of the head behind the auricle which covers the bony mastoid process and on which a bone vibrator is placed.

*material impairment*: is an average threshold exceeding 25 dB (HL) at the frequencies of 0.5, 1 and 2 kHz.\(^{246}\) It is thus identical to the World Health Organization definition\(^{247}\) of impairment of auditory sensitivity.

\(^{246}\)US Department of Labor – Occupational Safety and Health Administration (1981).

\(^{247}\)World Health Organization (1980).
**MCLL:** most comfortable loudness level.

**mean:** the arithmetic mean (colloquially termed the ‘average’) is the sum of all the observations divided by the number of observations. In hearing surveys, ‘the difference between “mean” and “median” hearing level can be significant . . . The mean, however . . . gives a better description of the sample when supplemented with standard deviations’. Mean hearing threshold levels are indeed particularly sensitive to clinical rejection criteria.  

**median:** the middle point when a series of measurements is ranked in ascending or descending order.

**mel:** the unit of pitch; 1 000 mels is the pitch of a 1 000 Hz tone at a sensation level of 40 dB.

**meta-analysis:** a structured and relatively unbiased framework for synthesizing information from a discordant group of logically related studies. It is the process of using statistical methods to combine the results of different studies, particularly when randomized controlled trials cannot be, or were not, done.

**middle ear:** the structure that, as its name implies, is interposed between the outer ear and the internal ear. Its function is to minimize loss of energy when sound passes from the air-containing external acoustic meatus to the fluid-filled internal ear.

**MKS:** the unifying system of units of measurement which is based on the metre, kilogram and second.

**mnemophysics:** the branch of psychophysics that deals with the quantitative relationships between physical stimuli and their remembered sensory properties (synonymous with memory psychophysics).

**mode:** the most frequently occurring value in a distribution.

**most comfortable loudness level:** the level at which an individual registers what he considers to be the most comfortable loudness for a sound (tone, speech units) that is presented to him (usually from an audiometer);

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provides a measure of loudness tolerance and an index of loudness
recruitment.

*MRC*: Medical Research Council (the main UK government body for the
promotion of medical and related biological research).

*MSFU*: Manufacturing Science Finance Union (successor to ASTMS).

*multiple regression equation*: a statistical numerical expression that
allows the value of one characteristic (variable) to be estimated when the
value of two or more other characteristics are known.

*multivariate analysis*: ‘a collection of techniques appropriate for situa-
tions in which the random variation in several variables has to be studied
simultaneously’ (Armitage, 1973, at p. 333); a *multiple regression
equation* results from such an analysis. The aim is to (a) disentangle
complex causative mechanisms that are influencing a particular phenom-
eron or measurement, (b) estimate the relative importance of each
contributing cause, and (c) predict more accurately what changes may be
expected in the phenomenon or measurement of interest when changes
occur in one or other of the other factors.

*n*: number of items, observations or measurements in a particular sample.

*N*: (a) symbol for newton; (b) sample size – the number in the sample. (‘N
should not be used for “normal”’ – Lowe, 1975).

*N*: (a) loudness; (b) component of hearing threshold level due to noise
exposure.

*NA*: *Nomina Anatomica*.

*NAL*: National Acoustic Laboratories (the official Australian Government
organization dealing with noise and with hearing); formerly the
Commonwealth Acoustic Laboratories.

*NAMAS*: National Accreditation of Measurement and Sampling (an NPL-
supervised calibration scheme).

*National Institute of Clinical Excellence*: for a decision as to whether or
not a new drug or interventional procedure will be used by the NHS
(England and Wales).
National Society for Clean Air and Environmental Protection: *inter alia*, promote noise awareness, for example by organizing National Noise Action Day (7 July 1999).

**NC**: noise criteria.

**network**: (computer terminology) a number of computers that are interconnected.

**neurotransmitter**: a specific body chemical that transmits the information contained in a nervous impulse from one nerve cell to the next.

**newton**: name of the SI unit of force.

**NFCB**: National Firearms Control Board (body proposed to oversee handgun control in the UK).

**NHS**: National Health Service.

**NHSME**: National Health Service Management Executive.

**NICE**: National Institute of Clinical Excellence.

**NIHL**: noise-induced hearing loss.

**NIL**: noise immission level.

**NIOSH**: National Institute for Occupational Safety and Health (set up under the US Department of Health, Education and Welfare which has now changed its name to the Department of Health and Human Services).

**NIPTS**: noise-induced permanent threshold shift.

**NIR**: noise immission rating on a scale of 0 to 4 (0 < 97 dB (NI); 1 = 97–107 dB (NI); 2 = 107–117 dB (NI); 3 = 117–127 dB (NI); 4 > 127 dB (NI)) (a measure used by the Medical Research Council’s Institute of Hearing Research).

**NIRG**: noise immission rating for exposure to noise from gunfire.

249 Because noise is going *into* the ear.
**NIRO**: noise immission rating for exposure to occupational noise.

**NIRS**: noise immission rating for exposure to social noise.

**NITTS**: noise-induced temporary threshold shift.

**NLR**: Nationaal Lucht- en Ruimtevaartlaboratorium (the National Aerospace Laboratory of the Netherlands).

**NOHL**: non-organic hearing loss.

*noise*: unwanted sound (but, as Berglund and Lindvall (1995) point out, ‘physically identical sound may become noise to one person and music to another, depending on whether one likes Mozart or rock and roll . . . The noise of the neighbor’s lawnmover [*sic*] may be annoying if (s)he mowed the lawn two days ago, but a pleasant relief if (s)he just returned from a six weeks vacation to clean up an overgrown front yard’ (at pp. 47–8).

**Noise and Nuisance Policy Unit**: a part of the Air and Environmental Quality Division of DETR.

*noise immission*: an index of the total noise energy incident on the ear over a specified period of time – a measure of noise going into the ear; the use of the term noise (or sound) ‘immission’ distinguishes the sound exposure experienced by an individual who might be moving from place to place from the sound level measured with an instrument (sound level meter) in a workplace.

*noise immission level*: a measure of noise exposure that takes into account both the level of the noise and the time for which an individual has been exposed to such a noise, combining these two factors into a single value that is expressed in dB (NI); employs equal energy principle (3 dB change for halving or doubling the time component) to trade these two factors one with the other. Basis of NPL Ac 61 model.

*noise pollution level*: an index of noise annoyance which takes into account not only the level of noise but also the fluctuation in that level (abbreviation NPL; symbol $L_{NP}$).

**Noise Rating Index**: ‘a partially objective measurement of pager and handphone blasts, 9pm and 10pm watch beeps, coughing-during-the-
pianissimo-bits, intra-audience conversation and other mind-boggling inept noises emitted in the concert hall during actual performance of music. It is measured on a scale of 0 to 5, in increasing annoyance.\textsuperscript{250}

\textit{Nomina Anatomica}: the official international list of anatomical terms which preceded the \textit{Terminologia Anatomica}.

\textit{Nomogram}: a type of line chart that shows the scales for the different measurements used in a formula and such that the corresponding values for each measurement lie in a straight line that cuts across all the scales, for example, the nomogram (Figure 2) for calculating the daily personal exposure to noise ($L_{ERd}$) in the HSE Noise Guide No. 3.

\textit{Normal distribution}: a synonym for \textit{Gaussian distribution}.

\textit{Normal threshold of hearing}: A term which should be avoided because of its medical and medicolegal implications.\textsuperscript{251} There is no single normal threshold of hearing. There are indeed a number of normal thresholds of normal hearing.

\textit{Nosoacusis}.\textsuperscript{252} hearing loss due to factors other than ageing, industrial and non-industrial noise exposure.

\textit{Noy}: the unit (subjective) of noisiness – parallels the \textit{sone for loudness}; thus a sound of 4 noys is four times as noisy as a sound of one noy.

\textit{NPL}: (a) National Physical Laboratory (the main UK government physics laboratory); (b) noise pollution level.

\textit{NR}: Noise Rating.

\textit{NRR}: Noise Reduction.

\textit{NRR}: Noise Reduction Rating, a single-number, laboratory-derived rating required by the Environmental Protection Agency (USA) to be shown on the label of each hearing protector sold in the USA.

\textsuperscript{250} NY Fan: http://inkpot.com/classical/mpo990410.html.

\textsuperscript{251} Davis and Silverman (1978, at p. 540).

\textsuperscript{252} Ward (1977).
NSAI: National Standards Authority of Ireland (the body which operates under the National Standards Authority of Ireland Act 1996, on behalf of the Minister for Enterprise and Employment, for the publication of national standards in Éire).

NSCA: National Society for Clean Air and Environmental Protection.

NSH: National Study of Hearing (the principal epidemiological programme of IHR).

OAD: abbreviation for obscure auditory dysfunction (see ADN).

OAE: otoacoustic emissions (may be spontaneous otoacoustic emissions or evoked otoacoustic emissions).


ONERA: Office National d’Etudes et de Recherche Aérospatiale (the French agency for aerospace research).

ONIHL: abbreviation for occupational noise induced hearing loss.

ontogeny: development of the individual.

operator: a symbol that specifies the type of calculation that one must perform on the elements of a formula, e.g. +, ×.

OSHA: Occupational Safety and Health Administration (USA).

otoacoustic emissions: sound energy which is emitted by the inner ear, either spontaneously or as evoked.

otological: relating to the ear. The ear has three component structures: the outer ear, the middle ear, and the inner ear, or labyrinth, and the last named is divided into the auditory labyrinth, or cochlea, and the vestibular labyrinth. An ear should not be termed ‘clinically otologically normal’ unless tests for the functional integrity of all the structural components of

253 More specifically, the outer hair cells of the cochlea.
the ear have been shown to be normal. So often an ear is referred to as being ‘otologically’ normal when the examiner has screened only for middle ear disorders, where the designation should be *tymanologically* normal. Hence the difficulty of reconciling these clinical concepts with the definition of ‘otological’ given by ISO 7029 (BS 6951).

**otoscope**: a hand-held instrument used to examine the outer ear passage and the eardrum; detachable tubular endpieces prevent the passage walls falling inward to obscure the view, which is facilitated by an illumination feature and varying degrees of magnification produced by lenses.

**ototoxic**: poisonous to the ear (usually used to describe certain pharmaceuticals that damage the hearing and/or balancing mechanism).

**outer ear passage**: a colloquial term for the *external acoustic meatus*.

**oxyacoia**: see *oxyaecoia*.

**oxyaecoia**: enhanced sensitivity to sounds due to having a threshold of hearing that is lower than that of the average person.

*P*: percentile.

*p*: symbol for *sound pressure*.

*P*: symbol for (a) peak pressure amplitude; (b) loudness level in *phons*.

*P*: acoustic power; unit: watt (symbol W).

*Pa*: symbol for the SI unit of pressure (*p*), the *pascal*.

**PAN**: European Commission’s *Protection Against Noise* Programme (EC’s Concerted Action Contract BMH4-CT96-0110 with the ILO).

**para-**: a prefix that denotes a departure from the normal.

**parabola**: a polynomial equation of the second degree.

**paracusis**: a term usually applied to the various disorders of auditory perception other than an elevation of the hearing threshold level, whether partial (*hypoacusis*) or complete (*anacusis*). More colloquially, the term
covers the various distortions of hearing such as diplacusis. These various distortions may be associated with, but are not specific to, noise damage to the hearing.

paracusis loci: impaired, including absent, ability to determine the location of a sound source.

parameter: a variable that partly or wholly characterizes a probability distribution.

paratelic state: a playful state in which the ongoing activity is engaged in for its own sake (a concept of reversal theory; para – Greek for ‘alongside’ the ‘telic’ state).

participation: participation involves all areas or aspects of human life, including full experience of being involved in a practice, custom, or social behaviour. The domains of participation – personal maintenance, mobility, exchange of information, social relationships, occupation, economic life and civil and community life – are ‘social’ in the sense that the character of these complex experiences is shaped by society; it refers to the complete lived experience of people with health conditions in the actual context in which they live. This context includes the environmental factors – physical, social, and the attitudinal world. Participation is therefore based on an ecological/environmental interaction model. A value is attached to restriction of participation (disadvantage). This value depends on cultural norms, so that a person can be disadvantaged in one group, location or country and not in another time or place or with a different status; moreover other contextual factors all contribute to participation. The standard or norm against which a person’s participation is compared represents the nature and extent of participation of a person without disablement in that society, culture or subculture.254

participation restriction: a disadvantage, for a person with an impairment or disability, that is created, or worsened, by features of the contextual factors, that is environmental and personal factors. The disadvantage may take many forms: the creation of additional disablement (a mental impairment such as pain, anguish or mental illness, or a mental or physical disability), or some diminishing of the degree or extent of participation.

254 Beta-1 Draft version of ICIDH-2 (WHO).
that is expected of an individual without disablement in that culture or society.\textsuperscript{255}

\textit{particle velocity}: the alternating component of the velocity of movement of the medium in a sound field.

\textit{pascal}: the SI unit for pressure.

\textit{pathognomonic}: a symptom or sign (clinical or found on a special test) which is specific to a given disorder or disease and not found in any other condition.

\textit{PCD}: programmed cell death (synonymous with \textit{apoptosis}).

\textit{PD}: Pensionable Disability (term used by Workers Compensation of various Canadian Provinces).

\textit{PDF}: Permanent Defence Force (of Éire).

\textit{PDFORRA}: Permanent Defence Forces Ordinary Ranks Representative Association (the trade union for non-commissioned officers and men in the Armed Services of Éire).

\textit{peak level}: highest pressure level achieved by an impulse noise.

\textit{percentile}: ‘the set of divisions that produce exactly 100 equal parts in a series of continuous values, such as height, weight’ (Last, 1995). Different sets of statistics may differ in respect of the direction in which they express percentiles for a given distribution. For example, with the NSH statistics, the 10th percentile for a particular hearing threshold indicates that 10\% of the population to which the data apply are estimated to have a threshold equal to or less than, i.e. better than, that threshold (Davis, 1995). The opposite direction is employed by the National Physical Laboratory for the tables in Ac 61 (Robinson and Shipton, 1977) and in Ac 94 (Shipton, 1979).

\textit{period prevalence}: the proportion of a defined group having a condition at any time within a stipulated period.

\textit{personal factors}: the background of a person’s life and living that is composed of features of him or herself that are not parts of a health condi-

\textsuperscript{255} Beta-1 Draft version of ICIDH-2 (WHO).
tion or disablement, including age, race, gender, educational background, experiences, personality and character style, aptitudes, other health conditions, fitness, lifestyle, habits, upbringing, coping styles, social background, profession and past and current experience.256

**pharyngotympanic tube**: the air-filled tube which connects the back of the nose with the air-containing middle ear cavity.

**phonom**: the unit of loudness level; 40 phons is the loudness level of a 40 dB SPL 1 kHz tone.

**phonophobia**: a morbid fear of one or other sound, including one’s own voice.

**phylogeny**: the evolutionary development of the species.

**pinna**: an alternative term for the auricle.

**pitch**: the subjective magnitude of frequency; the unit is the mel.

**pk**: peak (an abbreviation that is used on ‘echo’ reports).

**pleiotropy**: multiple effects from a single cause.

**PLU**: personal loudness units.

**PST**: prolonged spontaneous tinnitus.

**PN_{db}**: perceived noisiness in decibels;257 analogous to the **phon** for loudness.

**point prevalence**: the proportion of a defined group having a condition at one point in time.

**polynomial equation**: an equation of the type:

\[ y = \alpha + \beta_1x + \beta_2x^2 + \ldots + \beta_nx^n. \]

The highest power of \( x \), denoted here by \( n \), is referred to as the degree of the polynomial. When a relationship between two variables is other than a

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256 Beta-1 Draft version of ICIDH-2 (WHO).

257 Kryter (1959).
straight line, and the curve that expresses the relationship cannot be
‘straightened out’ by transforming either or both of the measures (for
example, by a logarithmic transformation), then a polynomial can be
useful employed. Curves of polynomial equations exhibit a number of
bends (one less than the degree of the polynomial).

*post-*: after; for example, postauricular (behind the ear).

*post-traumatic stress disorder*: a psychiatric disorder (F43.1 of ICD-10) that
arises as a delayed or protracted response to a stressful event or situation (of
either brief or long duration) of an exceptionally threatening or catastrophic
nature, which is likely to cause pervasive distress in almost anyone.

Predisposing factors, such as personality traits or previous history of neurotic
illness, may lower the threshold for the development of the syndrome or
aggravate its course, but they are neither necessary nor sufficient to explain
its occurrence. Typical features include episodes of repeated reliving of the
trauma in intrusive memories (‘flashbacks’), dreams or nightmares, occur-
ing against the persisting background of a sense of ‘numbness’ and
emotional blunting, detachment from other people, unresponsiveness to
other people, unresponsiveness to surroundings, *anhedonia*, and avoidance
of activities and situations reminiscent of the trauma.

*power function*: a function that is defined by the expression:

\[ y = kx^n \]

where

- \( y \) = dependent variable
- \( x \) = independent variable
- \( k \) = a constant
- \( n \) = exponent (index).

The *psychophysical function* has been expressed as a power function:

\[ \psi = k(\phi - \phi_0)^n \]

where

- \( \psi \) = subjective magnitude of the stimulus
- \( \phi \) = physical magnitude of the stimulus
- \( \phi_0 \) = physical magnitude of stimulus at threshold
- \( k \) = a constant (scaling factor)
- \( n \) = exponent (index)

so that \( \log \psi = n \log (\phi - \phi_0) + \log k \)
Therefore data that conform to this power function show a straight line when the logarithm of ψ is plotted against the logarithm of (φ – φ₀); the slope of the line is the exponent, \( n \), and the intercept is \( \log k \).

**PPE**: personal protective equipment, of which hearing protectors form a special case.

**pre-**: before.

**presbyacusis**: a diagnostic term applied by clinicians to explain the difficulties in hearing of older people; strictly speaking such a term should be used only after a medical examination has shown no cause for a patient’s hearing difficulties apart from an age-related permanent threshold shift that is of sufficient degree to constitute a hearing loss.

**pressure-envelope duration (B duration)**: the total time that the envelope of the pressure fluctuations (positive and negative) is within 20 dB of the peak pressure level.

**pressure-wave duration (A duration)**: the time required for the initial or principal pressure wave of an impulse noise to rise to its positive peak and return momentarily to ambient pressure.

**prevalence**: the number of cases in a population who have a condition at a given time. More specifically, there is point prevalence and period prevalence.

**principal component analysis**: a method of multivariate analysis.

**probability**: the likelihood that some event will occur or that some proposition is true.

**prognosis**: a forecast of how things medical (a patient, his or her disease, or a function) will turn out in the future.

**protocol**: (computer terminology) that which defines how computers communicate; it is an agreement between different systems on how they will work together; the set of TCP/IP protocols defines how computers on the Internet exchange information.

**psychophysical function**: the mathematical expression that relates the subjective magnitude of a stimulus to its physical magnitude. Until the
1950s this was considered to be a logarithmic function; the scientific evidence accumulated over the past half-century indicates it to be a power function.

*psychophysics*: the science that studies the relationship between physical stimuli and the resulting sensations.

*Pt*: patient.

*PTA*: abbreviation for pure-tone audiogram.

*PTS*: *Post-traumatic stress disorder*; permanent threshold shift.

*PULHEEMS*: the acronymic classification of medical fitness used by the British Armed Services, the letters representing Physical capacity (P), Upper limb (U), Lower limb (L), Hearing (H), visual acuity (EE – right and left eyes), Mental capacity (M) and Emotional Stability (S). A numerical grade is assigned to each letter.

*pure tone audiometer*: an audiometer that uses pure tones to measure a subject’s ability to hear, in particular, the quietest sounds that he can detect (threshold of hearing).

*PWL*: abbreviation for *sound power level*.

*Q₁*: the lower quartile.

*Q₃*: the upper quartile.

*quadratic*: a polynomial equation of the fourth degree.

*qualia*: first hand experiences (a term used by Dennett, 1998).

*R*: when used in designating ISO standards it precedes a number in order to indicate that that number is the one that is ‘R’ecommended to be the number which should be assigned to that standard (so an R prefix will also indicate that that standard is the first one to appear under that name).

*R*: electrical resistance.

*RACO*: Representative Association of Commissioned Officers (the trade union for commissioned officers in the armed services of Éire).
randomized controlled trial: a specific type of experimental investigation undertaken to determine the effect of one or more factors that are suspected, or known, to have an effect on man. Such experiments are characterized by comparison, replication, randomization, and objectivity. All measurement is essentially comparative (the ‘control’); replication provides a measure of experimental error; randomization is directed towards the elimination of bias.

**range:** the difference between the minimum and maximum values for a measurement.

**range of normal hearing:** the scatter of actual determinations of hearing sensitivity of normal-hearing persons with respect to age and gender. Sometimes the limit is taken arbitrarily as two standard deviations from the mean, sometimes as the 95th percentile.

**RCT:** randomized controlled trial.

**real ear at threshold:** a test method for measuring the sound attenuation of hearing protective devices by recording the subject’s change in hearing threshold when wearing the device and when not.

**REAT:** real ear at threshold.

**recall bias:** due to an individual affected by a particular condition having more reason to recall past exposure to an alleged causative factor than a control subject (a bias to which case-control studies are prone).

**recapitulation, Haeckel’s theory (or law) of:** in their embryonic development, individuals pass through stages similar in general structural plan to the stages that their species passed through in its evolution – *ontogeny* is an abbreviated recapitulation of *phylogeny* (law of biogenesis).

**receiver operating-characteristic:** a term used in signal detection theory; receiver operating-characteristic curves show the probability of a true positive response versus a false positive response with the detectability measure of $d'$ as the parameter.

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258 Perhaps better termed an *experimental comparative study.*
regression equation: a statistical numerical expression that allows the value of one characteristic (variable) to be estimated when the value of another characteristic is known.

rehabilitation: ‘a process aimed at enabling persons with disabilities to reach and maintain their optimal physical, sensory, intellectual, psychiatric and/or social functional levels, thus providing them with the tools to change their lives towards a higher level of independence. Rehabilitation may include measures to provide and/or restore functions, or compensate for the loss or absence of a function or for a functional limitation. The rehabilitation process does not involve initial medical care’ (paragraph 23, UN Standard Rules, 1994).

REL: recommended exposure limit.259

REPRO: reproducibility.

residua: plural of residuum.

residuum: that which is left behind, for example scarred eardrums following middle ear infection.

retrodiction:260 the converse of prediction – determining the course of events that have already happened, but of which one has no certain knowledge.261

retrognosis: a term (by analogy with prognosis) which covers endeavours to ascertain the course of development of a disorder, or malfunction, prior to a particular time, usually the time of a particular examination followed by a consequent report. It would therefore include looking not only at events of which one has no certain knowledge, for example retrospection, which looks at thresholds of hearing, and retrodiction, which looks at matters other than thresholds of hearing, but also matters for which there is certain knowledge – for example events for which there are contemporaneous records, as in the health and occupational records for a particular individual. It is essentially a reconstruction of the individual’s life prior to a particular time.

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259 Sound levels.
261 Hanson (1958, at p. 51).
retrospection: ‘an exercise which involves looking back along the course of the individual’s history of hearing loss, starting with the measured hearing loss at the present time . . . the foreword to the tables (NPL Ac 61) makes it clear that they are not intended for use to predict individual hearing losses . . . When used prospectively, three facts are known or assumed – the subject’s initial hearing loss (nil), the continuous noise immission level, and the duration of exposure. These facts are not enough to enable a precise prediction of the course of the subject’s hearing loss in the future, and of the impairment at which he will arrive at the period of exposure. This is so because of the very wide variation in the amount of the loss, as represented by the figures attributable to the different percentiles . . . But the position is crucially different where retrospection is in issue. Here, there is an additional known fact, namely the actual hearing loss at the end of the period. By enabling the subject’s assignment to a percentile, this enables a much more reliable view to be formed of his losses in the past . . .’ (in the judgment of Mr Justice Mustill in Thompson, Gray and Nicholson v Smiths Shiprepairers (North Shields) Ltd; Blacklock and Waggott v Swan Hunter Shipbuilders Ltd; Mitchell v Vickers Armstrong Ltd and the Swan Hunter Shipbuilders Ltd [1984] 1 All ER 881 at p. 51). This approval makes it possible for the medical examiner to produce a reconstruction of the time course of a claimant’s hearing acuity as he came to be exposed to hazardous noise levels. This reconstruction is required by the lawyers for their apportionment exercises.

RETSPL: reference equivalent threshold sound pressure level (in dB re 20 µPa).

RHINO: acronym for Reduction of Helicopter Internal Noise, a specific activity directed towards the reduction of noise levels within helicopters (in contrast to the HELINOISE programme), which is supported by the EU.

rigorous: conforming strictly to the canons of valid argumentation (in contrast to common sense or heuristic).

rise time: the time taken for the single pressure fluctuation that forms the initial or principal positive peak of an impulse noise to increase from the ambient to the peak pressure level.

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262 He probably meant the equivalent continuous sound level.
263 Near instantaneous for gunfire.
**risk**: a term used in standards and other documents to express the chance of hearing disability due to occupational noise exposure; in BS 5330 this is specified in terms of the percentage of the population expected to exceed the low fence; in ISO 1999 the risk is defined as the difference in exceedence – the percentage of a noise-exposed population that would exceed a low fence less the percentage of a corresponding non-exposed population that would exceed that same low fence.

**RL**: reverberation level.

**RMS**: root mean square.

**RNID**: Royal National Institute for Deaf People:\(^{264}\) the principal non-governmental body in the UK that looks after the interests of deaf and hearing impaired people.

**ROC**: receiver operating-characteristic.

**round window membrane**: see secondary tympanic membrane.

**RSA**: (a) The Royal Society for the encouragement of Arts, Manufactures and Commerce; (b) Radiation Science and Acoustics (a division of NPL).

**Rudmose audiometer**:\(^{265}\) an automatic recording audiometer that tests a subject’s hearing using a fixed frequency test tone only (used in industrial hearing conservation programmes).

**s**: symbol for second.

**S**: symbol for (a) loudness (expressed in sones); (b) surface area.

**Safety and Efficacy Register of New Interventional Procedures**: the body to which all new interventional procedures must be reported (UK).

**SAGBNI**: The Sportsman’s Association of Great Britain and Northern Ireland.\(^ {266}\)

**SAM**: surface to air missile.

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\(^{264}\) Name changed in 1992 from the Royal National Institute for the Deaf.

\(^{265}\) Named after its designer, Wayne Rudmose, then Professor Physics at Southern Methodist University, Dallas, Texas.

\(^{266}\) A Shrewsbury-based association.
**scarred eardrum**: an eardrum that is marked as a result of previous damage. An ear so affected is therefore not ‘otologically normal’.

**scattergraph**: a graph that shows a collection of points, the position of each point being determined by the magnitude of each of the two measures (dependent and independent variables) as it relates to that point. Such a graph depicts visually the degree of correlation between the two measures. If there is no correlation the plotted points are scattered all over the graph (‘snowstorm’ pattern). If there is a correlation then some pattern emerges. For example, if one variable increases in magnitude at the same time as the other variable increases in magnitude, then there is a positive correlation. If the pattern follows a straight line, we have a positive linear correlation; if the pattern is curved then the correlation is a curvilinear one. With most biological, medical and psychological data the points of correlated measures do not follow exactly one particular line or curve, the points lying within a band, whose width is determined by the strength of the correlation; selecting the best or most appropriate line or curve to describe the data is known as **curve fitting**.

**Scottish Intercollegiate Guidelines Network**: a collaborative Scottish development that produces guidelines for the healthcare specialties. The establishment of each guideline starts with a systematic review à la Cochrane, everything being annotated with a grading of the evidence.

**SD**: standard deviation.

**secondary tympanic membrane**: a small, very thin membrane that separates the middle ear cavity from the internal ear (colloquially termed the **round window membrane**).

**secular trend**: long-term change in a time series, for example over a period of years.

**semeion**: any untoward phenomenon, or departure from the normal in structure, function or sensation, which is experienced by an individual, or noted by another person, but which is elicited only by direct questioning and is not spontaneously reported; such a person is termed a respondent (not a patient).

**SENEL**: single event noise exposure level.

**sensation level**: see **level above threshold**.
**sequela:** a condition following on, and as a consequence of, a disease (essentially permanent pathological states that follow the resolution of an active disease process).

**SERNIP:** Safety and Efficacy Register of New Interventional Procedures.

**serotonin:** a neurotransmitter (physiological chemical), 5-hydroxytryptamine, that influences the calibre of blood vessels, body secretions and psychological states.

**sex:** one of two types (female or male) of a given species that are responsible for the procreation of that species (sometimes referred to as gender).

**shp:** shaft horse power, an alternative to kilowatts for expressing turboshaft power, for example for helicopters.

**SI:** the international abbreviation for Le Système International d’Unités.

**sibilant:** a particular subgroup of fricatives (the hissing consonants): /θ/, /s/ and /ʃ/.

**sign:** any abnormality discoverable on examination of a patient that is indicative of injury or disease.

**SIGN:** Scottish Intercollegiate Guidelines Network.

**significant other:** a person within an individual’s social environment who is so closely associated, for example spouse, companion, parent, child, workmate, as to be affected by any impairment sustained by that individual.

**significant threshold shift:** ‘A shift in hearing threshold, outside the range of audiometric testing variability (± 5 dB), that warrants follow-up action to prevent further hearing loss. NIOSH recommends that a change in hearing threshold of 15 dB for the worse at any frequency (0.5, 1, 2, 3, 4, or 6 kHz) that is repeated for the same ear and frequency to meet the criteria for significant threshold shift’ (NIOSH, 1996).

**SIL:** speech interference level.

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267 As in *thin.*
**sinb**: abbreviation for *hyperbolic sine*; pronounced as ‘shine’ or ‘sinch’.

**sinus**: (a) name applied to some channels for the passage of body fluids; (b) a depression or blind passage on a surface of, or within, the body.

**SISI**: Short Increment Sensitivity Index (a test of the ability to detect small differences in sound intensity).

**size constancy**: appearance that an object has the same size when viewed at different distances despite the fact that, at different distances, the object produces different sized stimulations of the retina.

**SL**: *sensation level*.

**s.leq**: sample equivalent continuous noise level.

**SLM**: sound level meter.

**SLR**: self-loading rifle.

**SMG**: sub-machine gun.

**S/N**: serial number.

**SNHL**: sensorineural hearing loss (formerly referred to as ‘perceptive deafness’ or ‘inner ear deafness’).

**SNR**: signal to noise ratio (an abbreviation that is used on ‘echo’ reports).

**SOAE**: spontaneous otoacoustic emissions.

**social psychology**: that branch of psychology concerned with the scientific study of the behaviour of individuals as influenced, directly or indirectly, by social stimuli. Social psychologists are interested in the thinking, emotions, desires and judgements of individuals, as well as their overt behaviour.

**socioacusis**: non-industrial noise-induced threshold shifts.

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sone: the unit of loudness; one sone is the loudness of a sound whose loudness level $P$ is 40 phons; loudness $S$ in sones is related to loudness level in phons by the relation:

$$S = 2^{(P-40)/10}$$

(BS 4198).

sound intensity: the sound energy that crosses one square metre every second at a given position; expressed as watts per square metre (W m$^{-2}$).

sound level meter: an instrument used for measuring sound levels.

sound power level: the power of a sound expressed in decibels with respect to a reference power, $W_0$, of one picowatt (1.0 pW, i.e. $10^{-12}$ W).

sound pressure: the alternating component of the pressure at a point in a sound field.

sound pressure level: the level of a sound pressure expressed relative to a sound pressure of 20 $\mu$Pa (micropascals); abbreviation SPL.

spectrum: the spectrum of a sound (or a wave) expresses the distribution, as a function of sound frequency, of the magnitudes (and sometimes phases) of the various components of the sound (or wave); in other words it tells us the frequency composition of a noise.

speech audiogram: an audiogram that portrays an individual’s ability to hear speech.

speech audiometer: an audiometer which uses one or other speech test materials to measure a subject’s ability to hear speech.

speech audiometry: audiometry conducted to assess an individual’s ability to hear speech.

SPL: sound pressure level.

SRA: (a) self-recording audiometry; (b) Shooter’s Rights Association$^{269}$ (founded in 1984 to preserve the legal rights of UK citizens to possess and use firearms).

$^{269}$ A Cardigan-based association.
SRT: speech reception threshold (a measure of ability to hear speech, which is analogous to hearing threshold level for hearing tones).

SSOAE: synchronized spontaneous otoacoustic emissions.

standard: a documented agreement containing a set of detailed guidelines used to specify the way that things are done or the equipment used to do certain things with the aim of achieving a particular quality including the limits of accuracy required; when accepted by one or other official body it becomes a National or International Standard.

standard deviation: a measure of the dispersion of a set of data, specifically, the square root of the variance.

standard threshold shift: a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at 2000, 3000 and 4000 Hz in either ear (Occupational noise exposure: US Department of Labor Occupational Noise Exposure Standard – Code of Federal Regulations, Title 29, Chapter XVII, Part 1910, Subpart G, para (g)(10) of § 19.10.95, 29 May 1971; Amended by 48 FR 9776, March 8, 1983). ‘In determining whether a standard threshold shift has occurred allowance may be made by correcting the annual audiogram . . .’

statement: an assertion that is either true or false.

state of health: a general description of the degree to which an individual, or group, or a population, functions normally, both physically and mentally, with respect to accepted criteria (synonymous with health status).

statistics: (a) quantitative data affected to a marked extent by a multiplicity of causes; (b) a set of numbers that specifies a large body of data; (c) that branch of mathematical knowledge that is able to draw rigorous conclusions from variable material, the conclusions being framed in terms of probability.

steady state noise: noise whose sound level stays constant.

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270 Not with respect to ISO 7029 or any other standard.
271 Thus a NPTS of 30 dB at 4 kHz would go undetected (or, rather, unreported) if the change at 2 kHz had been –5 dB (due to measurement uncertainty) and that at 3 kHz, 0 dB; this OSHA criterion is therefore relatively insensitive.
272 OSHA (Occupational Safety and Health Administration) Hearing Conservation Amendment.
273 In logic.
**stochastic damage (effects of radiation):** the late effects of radiation exposure that show as a long-term risk for the development of malignant disease and the possible production of inheritable abnormalities.

**STS:** abbreviation for *standard threshold shift* (US). Serological test for syphilis.

**subclinical:** refers to the early stage, or mild degree, of a disorder when it is insufficiently developed to give rise to symptoms.

**sub-experimental study:** a population study in which one or more observations, including measurements, are made but there is no attempt to manipulate the existence or strength of any factor, nor whether or not an individual is exposed to one or other factor. It is indeed essentially an observational study, and, as such, it is unable to control the extent that one or other factor outside the immediate area of interest is influencing the observations, and hence the conclusions of the study. Sub-experimental studies include *cohort* studies, *case-control* studies and studies of *case series*.

**substrate:** the chemical upon which an *enzyme* works.

**‘supersonic sickness’:** see *ultrasonic sickness*.

**survey:** a study of one or more defined, naturally occurring populations to ascertain the ‘strength’ of one or more factors and ascertain the extent to which these factors are influenced by other factors, for example the MRC/NPL Survey of Noise and Hearing in Industry, the National Study of Hearing. There are often confounding factors that can be eliminated only by specifically designed experiments.

**susceptibility:** likelihood of an individual developing ill effects from an external agent, such as tuberculosis (due to a micro-organism), high altitude sickness (due to decreased oxygen available), or occupational noise-induced hearing loss. In many contexts, including in formulae and tables that relate hearing threshold levels to ageing and/or noise damage, what is referred to as ‘susceptibility’ is strictly the ‘as yet unexplained variance’.²⁷⁴ This would cover factors other than those specified in the formulae, such as age, gender, socio-economic level and noise exposure, which affect hearing threshold levels, as well as the influence of other diseases.

²⁷⁴ Essentially, the degree of deviation of a measure, for example hearing threshold level, from average values.
symbol: a character (or characters) that represents, and has usually been adopted by one or other official body, to represent, for example, a concept, measurement or measurement unit, such as +, y and Hz to indicate addition, a variable and bertz (the unit of frequency) respectively.

symptom: any untoward phenomenon, or departure from the normal in structure, function or sensation, which is experienced by a patient, or noted by another person, and spontaneously reported to the doctor when medical advice is sought.

syndrome: an aggregation of a particular collection of symptoms and/or signs, which is the manifestation of one or other underlying disease processes that are responsible for such symptoms and signs.

*Système International d’Unités, Le*: The International System of Units.\(^\text{275}\)

\(T\): (a) a measured length of time; (b) reverberation time.

\(TA\): Terminologia Anatomica (successor to Nomina Anatomica).

tanh: abbreviation for hyperbolic tangent; pronounced as ‘tansh’ or ‘than’ (with the ‘th’ as in ‘thing’).

\(TC\): Technical Committee.

\(TCP/IP\): Transmission Control Protocol/Internet Protocol (the set of protocols that drive the Internet, regulating how data are transferred between computers).

telic state: a serious-minded state in which the individual sees himself as engaged in some purposeful activity that is important beyond itself (a concept of Reversal Theory).

\(TEU\): *Treaty on European Union*.

**threshold of inability**: threshold at which *ability* begins to be lost.\(^\text{276}\)

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\(^{275}\) This international system, based on the MKS system, was initially proposed by the Italian physicist, Giorgi, in 1901. The IEC Advisory Committee on Nomenclature recommended it in 1935, and the IEC and other international science bodies endorsed it in 1938.

\(^{276}\) Robinson et al. (1984).
threshold shift, noise-induced permanent (NIPTS): the term that has been used for several decades by workers in the field of noise-induced damage to hearing to designate the permanent noise component in a threshold of hearing that would be attributable to noise damage.

*Ti*: abbreviation for tinnitus.

time varying noise exposure: sound level varies but remains above effective quiet.

time-weighted average: the sound level that, if constant over an eight-hour day, would result in the same exposure as the noise exposure in question (assuming a 5 dB doubling/halving rule) (USA).

tinnitus: a sensation of sound which is not associated with any external acoustic, electrical or mechanical stimulus.

*TM*: (a) tympanic membrane (eardrum); (b) trade mark (when used as a superscripted suffix; US for proprietary pharmaceutical preparations); (c) transcendental meditation.


traceability: the ability to trace back any measurement through a chain of calibrations to the primary standard.

*Treaty on European Union (signed on 7 February 1992 in Maastricht)*: produced substantial amendments to EEC Treaty and renamed it the EC Treaty.

*TTS*: abbreviation for noise-induced temporary threshold shift (also NITTS).

*TUC*: Trades Union Congress.

*TUL*: threshold of uncomfortable loudness (as determined by audiometric testing, usually for pure tones).

*Tullio effect (or phenomenon)*: symptoms of unsteadiness due to exposure to high noise levels, which symptoms are mild and transitory with no permanent ill-effects (attributable to intense stimulation of vestibular labyrinth with acoustic energy in audible frequency range).

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277 In contrast to noise-induced temporary threshold shift (NITTS).
**TWA**: time-weighted average (USA).

**tympanic membrane**: technical term for the eardrum, the structure that separates the outer ear canal from the middle ear cavity.

**tympanological**: relating to the middle ear.

**tympanosclerosis**: an abnormal appearance of the eardrum that shows as one or more white areas (sometimes referred to as ‘chalk patches’) which represent a healing process (ending in calcifications) following middle ear infections; may extend inwards to involve other middle ear structures.

**u**: a centile parameter in the NPL noise/hearing formula which is related to the percentage of population \( p \) by the equation

\[
u = 6\sqrt{2} \text{erf}^{-1}\left\{(p/50) - 1\right\}.
\]

(\( u \) is a normally distributed variate with standard deviation 6 dB.)

**u**: particle velocity.

**U**: volume velocity.

**UKCOD**: United Kingdom Council for Organizations on Deafness (UK umbrella organization for the various associations and other bodies concerned with deafness and hearing impairment).

**ULL**: uncomfortable loudness level – but as there are many uncomfortable loudness levels, it is preferable to refer to the threshold of uncomfortable loudness (TUL), which the ULL test purports to determine.

‘**ultrasonic sickness’**: a term used over the period 1948/52 to describe symptoms attributed to exposure to ultrasound (usually from jet engines); now considered to have been largely psychosomatic ‘and engendered by the apprehension and/or fear growing out of speculative publicity about the effects of air-borne ultrasound’ (Parrack, 1966); symptoms of unsteadiness are, however, due to **Tullio effect**.

**ultrasound**: sound composed of frequencies above the audible range.

**UNDP**: United Nations Development Programme.


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**UNIDO**: United Nations Industrial Development Organization.

**UNIFIL**: United Nations Interim Force in Lebanon.

**upper quartile**: the value above which one quarter of the ordered observations fall.

**URL**: Uniform Resource Location (technical term for a web site).

**USAF**: United States Air Force.

**variable**: a quantity that does not take a fixed value, for example an individual's sex or hearing threshold level.

**variance**: the mean value of the squared deviations from the mean.

**variate**: a quantity with which a probability distribution is associated, for example height, hearing threshold level.

**VDI**: Verein Deutscher Ingenieure.

**Verein Deutscher Ingenieure**: Association of German Engineers.

**vertigo**: a type of dizziness/giddiness that is characterized by a hallucination of movement.

**vestibular labyrinth**: that part of the internal ear, which is the organ of balance. It is not affected by occupational noise exposure with the exception of the temporary Tullio effect but a number of other disorders that affect the cochlear labyrinth may also affect this structure; malfunctioning of this organ is characterized by episodes of vertigo.

**VL**: voice level.

**volume velocity**: the rate of flow of the alternating component through a specified area.

**VWF**: vibration white finger (now referred to as HAVS).

**W**: symbol for power.
Walsh–Healey Public Contracts Act: The 1969 law in which the US government first incorporated noise regulations. It applied to companies that had government contracts of over US$10 000. Noise exposure of 90 dB(A) for an eight-hour work shift was permitted. For every halving of the shift duration the level could be increased by 5 dB(A) up to a limit of 115 dB(A). A limit of 140 dB for peak sound pressure levels; subsequently became applicable to all industries with the passing of the 1970 Occupational Safety and Health Act.

watt: the SI unit of power (symbol, W).

WBV: whole body vibration.

WCB: Workers’ Compensation Board (name of the body in the various Canadian provinces that is responsible for awarding compensation to workers).

WECPNL: weighted equivalent community perceived noise level (a measure of the intrusive effects of environmental noise, which was recommended by the International Organization of Aviation. Used in Japan and elsewhere).

WG: Working Group.

WHO: World Health Organization.

Y: age in years.

References for the glossary

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Wacholder S, Silverman DT, McLaughlin JK, Mandel JS (1992) Selection of controls in
case-control studies: II Types of controls. American Journal of Epidemiology 135:
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World Health Organization (1997) Conclusions and Recommendations of First
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Activities and Participation – A Manual of Dimensions of Disablement and
PART IV
Chronology of Development of Knowledge and Practice Relevant to ONIHL
<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Publication</th>
<th>Medical/scientific relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1886</td>
<td>Barr</td>
<td>Proceedings of Glasgow Philosophical Society 17: 223–9</td>
<td>First description by a British clinician of ONIHL. The observation that tinnitus is not a conspicuous feature of the condition.</td>
</tr>
<tr>
<td>1940</td>
<td>Beasley</td>
<td>Laryngoscope 50: 856–905, at p. 890</td>
<td>Provided that the hearing is normal, or nearly so, for frequencies up to 2 kHz, an individual should <em>not be aware of any hearing defect</em>.</td>
</tr>
<tr>
<td>1947</td>
<td>Békésy</td>
<td>Acta oto-laryngologica 35: 411–22</td>
<td>Description of a new audiometer that provides a self-recording of hearing threshold, so cutting out the audiometrician with all the errors associated with such an operator.</td>
</tr>
<tr>
<td>1947</td>
<td>Committee on Electro-acoustics, Medical Research Council</td>
<td>MRC Special Report Series No. 261</td>
<td>In considering the design of hearing aids, decided that ‘a cut-off above 4,000 c/s was not detrimental to intelligibility’.</td>
</tr>
</tbody>
</table>

279 Viewed solely in medical/scientific, and not necessarily, legal terms.
280 See Fearn and Hanson (1983).
<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Publication</th>
<th>Medical/scientific relevance</th>
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</thead>
<tbody>
<tr>
<td>1953</td>
<td>Johnston</td>
<td>British Journal of Industrial Medicine 10: 41–50</td>
<td>First audiometric study of ONIHL in UK. Tinnitus occurs during earlier years but is not a problem.</td>
</tr>
<tr>
<td>1953</td>
<td>Venters</td>
<td>Proceedings of the Royal Society of Medicine 46: 825–9</td>
<td>Of 254 cases of tinnitus seen in clinical practice, in only one case (a boilermaker) was the tinnitus attributed to occupational noise damage to the hearing. This was despite the fact that there was a definite aural hazard (defined as employment in ‘such industries as boilermaking, heavy engineering, sheet metal workers, mining and certain types of factories’) in the population that otologist served.</td>
</tr>
<tr>
<td>1953</td>
<td>Heller, Bergman</td>
<td>Annals of Otology, Rhinology and Laryngology 62: 73–83</td>
<td>We can all experience tinnitus if the conditions (especially ambient sound levels) are right.</td>
</tr>
<tr>
<td>1954</td>
<td>King</td>
<td>Journal of Laryngology and Otology 68: 623–35</td>
<td>Royal Air Force otologist reports case histories of patients who complain of difficulties in hearing but who have essentially normal thresholds of hearing; distinguished condition from malingering and assigned patients to a subclass of ‘psychogenic deafness’, which Kopetzky had termed ‘loss of discrimination faculty’. It was accepted by clinicians that individuals can complain about their hearing and have normal audiograms but are not malingering.</td>
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</table>

\(^{281}\)The use of the word ‘normal’ was unfortunate as it implied that any other threshold measured was abnormal.
<table>
<thead>
<tr>
<th>Year</th>
<th>Author(s)</th>
<th>Source</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>Keatinge, Laner</td>
<td>British Journal of Industrial Medicine</td>
<td>First UK audiometric study of growth of occupational noise-induced hearing loss (ONIHL) (essentially complete within three years of start of exposure)</td>
</tr>
<tr>
<td>1959</td>
<td>Hinchcliffe</td>
<td>Acta oto-laryngologica 50: 411–22.</td>
<td>Measurement of hearing on a random sample of rural young adults. For the frequency range 125 Hz/4 kHz, the 10 dB or so difference between the British and US Standards cannot be attributed to British Standard being based upon laboratory studies if one makes allowance for practice effect and method of measurement.</td>
</tr>
<tr>
<td>1959</td>
<td>Reilly</td>
<td>Medical Journal of Australia 7: 700–3.</td>
<td>A clinician pointing out that 4 kHz notch is not specific to noise damage.</td>
</tr>
<tr>
<td>1963</td>
<td>Ministry of Labour</td>
<td>Noise and the Worker. London: HMSO.</td>
<td>Date when employers ought to have known that industrial noise was a hazard to hearing and that they should and could be doing something about it.</td>
</tr>
<tr>
<td>Year</td>
<td>Authors</td>
<td>Publication</td>
<td>Medical/scientific relevance</td>
</tr>
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</tr>
<tr>
<td>1966</td>
<td>Knight</td>
<td>Journal of Acoustical Society of America 39: 1184–5</td>
<td>Previously reported 6 kHz Royal Navy (RN) notching was due to calibration error, but RN have 3 dB better hearing than RAF.(^{292})</td>
</tr>
<tr>
<td>1967</td>
<td>Coles</td>
<td>Journal of Speech and Hearing Disorders 32: 296–7</td>
<td>Pressure of the audiometer earphone on the soft structures of the ear can produce a spurious 70 dB 6 kHz notch.</td>
</tr>
<tr>
<td>1969</td>
<td>Lawrence, Byers</td>
<td>Journal of Speech and Hearing Research 12: 426–34</td>
<td>People with marked high frequency hearing losses (steep losses above 1 kHz descending to 50 dB to 70 dB at 2 kHz and 75 dB to 100 dB HTL) can identify high frequency consonants (use low frequency energy in, and the duration and intensity of, this particular group of speech sounds).</td>
</tr>
<tr>
<td>1970</td>
<td>Acton</td>
<td>Ergonomics 13: 546–54</td>
<td>Most important frequency for hearing speech is 2 kHz.</td>
</tr>
<tr>
<td>1970</td>
<td>Burns, Robinson</td>
<td>Hearing and Noise in Industry. London: HMSO</td>
<td>Report of a government-sponsored survey of hearing and noise in industry with the aim of demonstrating whether or not industrial noise exposure was a risk to employment (it was). The noise immission level concept (the expression of exposure noise level and exposure duration in a single composite ‘hazard’ value using the equal energy hypothesis – doubling exposure time is equivalent to increasing noise level by 3 dB) is enunciated.</td>
</tr>
</tbody>
</table>

\(^{292}\) Unlikely; probably attributable to Fearn factor.
<table>
<thead>
<tr>
<th>Year</th>
<th>Author(s)</th>
<th>Reference</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>Atherley, Noble</td>
<td>Clinical picture of occupational hearing loss obtained with the hearing measurement scale. In Robinson DW (ed.) Occupational Hearing Loss. London: Academic Press</td>
<td>A description of hearing <em>disabilities</em> in occupational noise-induced hearing loss. Only a half of a random sample of 38 drop forgers were free from ‘gross otological abnormality’. Less than 10% get tinnitus but it is not troublesome.</td>
</tr>
<tr>
<td>1971</td>
<td>Priede, Coles</td>
<td>Sound 5: 39–46</td>
<td>Development of <em>tolerance</em> to noise in individuals so exposed.</td>
</tr>
<tr>
<td>1972</td>
<td>Department of Employment</td>
<td>Code of Practice for Reducing the Exposure of Employed Persons to Noise. London: HMSO</td>
<td>Specific advice to employers on methods for controlling, measuring and recording noise levels, together with advice on hearing protection for workers, specifying a maximum noise level to which workers should be exposed, i.e. 90 dB(A).</td>
</tr>
<tr>
<td>1972</td>
<td>Kerns</td>
<td>Unpublished MSc thesis. University of Salford</td>
<td>Otological abnormality more common than not in factory workers in northwest of England; now that litigation has entered millibel range any abnormality can no longer be ignored.</td>
</tr>
<tr>
<td>1973</td>
<td>Merluzzi, Hinchcliffe</td>
<td>Audiology 12: 65–9</td>
<td>Report of thresholds of an age-dependent perceived auditory impairment for a rural population. An argument is advanced that the ‘low fence’ should correspond to 0 dB HTL. Having regard to how audiometry is conducted and reported on, claimants for such a criterion would include the majority, if not the whole, of the population. In the <em>individual</em> case how far down can one measure? Audiometric tolerances are ± 3 dB and audiometers move in 5 dB steps. Moreover, how much should one allow for ageing, gender and socioeconomic group? Furthermore if the measured threshold is better than the applicable threshold of perceived auditory impairment is this relevant to what the common law compensates?</td>
</tr>
<tr>
<td>Year</td>
<td>Authors</td>
<td>Publication</td>
<td>Medical/scientific relevance</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>1973</td>
<td>Pearson, Kell, Taylor</td>
<td>In Taylor W (ed.) Disorders of Auditory Function. London: Academic Press</td>
<td>If hearing threshold level is less than about 25 dB around 2 kHz, very few female jute weavers in Dundee report hearing difficulties, except for a ‘small group having difficulty in conversation against a noise background. This can probably be explained by a varying interpretation of “difficulty”. With a sufficiently loud background everyone has difficulty’.</td>
</tr>
<tr>
<td>1973</td>
<td>Industrial Injuries Advisory Council</td>
<td>Occupational Deafness (Cmnd. 5461).</td>
<td>Evidence of clinicians that clinical picture of occupational noise-induced hearing loss is non-specific.</td>
</tr>
<tr>
<td>1974</td>
<td>Secretary of State for Social Services</td>
<td></td>
<td>Prescribes occupational noise-induced hearing loss as an industrial disease.</td>
</tr>
</tbody>
</table>
(a) ‘Normal hearing and the threshold of handicap’. ‘Healthy young adults differ from one another with respect to the sensitivity of their hearing just as they differ with respect to height, weight, blood pressure, basal metabolism and many other anatomical and physiological characteristics . . . This range is generally considered to extend from the least intensity available on an audiometer to about 23 dB [HL (ANSI)]. Hearing threshold levels near either extreme may be considered unusual but not abnormal, although the occurrence of changes of sensitivity within the range of normal may have some diagnostic significance, particularly in children and adolescents’ (p. 276); (b) ‘Normal threshold of hearing’: a term that should be avoided because of its medical and medicolegal implications; there is no single normal threshold of hearing; there are ranges of normal hearing, (at p. 540); (c) ‘Hearing loss’: a term that should not be used to specify ‘hearing level’ or ‘hearing threshold shift’, which terms only should be quantified by a numerical value, which itself is specified in ‘decibels’ (at pp. 92, 542): ‘it is properly used in referring to a general medical condition such as “conductive hearing loss” or “a noise-induced hearing loss”. It emphasises the impairment of function. It is illogical and very confusing, however, to speak of a hearing loss of 20 dB (ISO), for example, because this value lies well within the range of normal. It is very difficult to explain this fact to a layman. He automatically thinks of a hearing loss as an impairment and often as a handicap’ (at p. 276).

Comparison of magnitudes of subjective ratings of ‘hearing handicap’ by hospital patients in London and in Cairo with audiometrically determined thresholds at 2 kHz; in view of subsequent WHO definition of ‘handicap’ and reflection on how patients were thinking, almost certainly this was a subjective magnitude of auditory impairment, as the title of the report said.
<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Publication</th>
<th>Medical/scientific relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>Prasansuk, Hinchcliffe</td>
<td>Journal of Medical Association of Thailand.</td>
<td>Like the preceding study, but this was conducted on hospital patients in Bangkok. A similar formula, but with different numerical values, was obtained. But how was ‘hearing handicap’ translated into Thai?</td>
</tr>
<tr>
<td>1979</td>
<td>Robinson, Sutton</td>
<td>Audiology 18: 320–34</td>
<td>This study analysed numerical data\textsuperscript{283} on age-associated hearing thresholds by looking at change so that variability arising from different methods\textsuperscript{284} of arriving at the hearing threshold level for young adults was neutralized.</td>
</tr>
<tr>
<td>1979</td>
<td>Shipton</td>
<td>Acoustics Report Ac 94, National Physical Laboratory</td>
<td>Presents formulae derived from previous study in tabular form and assumes median hearing threshold level is 0 dB for ‘otologically screened’ young adults.</td>
</tr>
<tr>
<td>1979</td>
<td>Hinchcliffe</td>
<td>In Maran and Stell’s Clinical Otolaryngology.</td>
<td>Demonstrates diagnostic value of Békésy audiometry in a book which ‘provides in one comprehensive volume all the principles of otolaryngology that the postgraduate student needs for the final Fellowship examination in the United Kingdom, Canada and Australia, or the Specialty Board examination in the United States of America’.</td>
</tr>
<tr>
<td>1980</td>
<td>WHO</td>
<td>International Classification of Impairments, Disabilities, and Handicaps</td>
<td>Provides authoritative international definition of impairment, disability and handicap</td>
</tr>
<tr>
<td>1981</td>
<td>Robinson, Shipton, Hinchcliffe</td>
<td>Audiology 1981; 20, 409–31.</td>
<td>(a) degrees of ‘otological’ abnormality; (b) International Standard for Audiometric Zero set too low at 500 Hz and 6 kHz</td>
</tr>
</tbody>
</table>

\textsuperscript{283} From eight sources, including three UK populations.  
\textsuperscript{284} Including population sampling, exclusion criteria, calibration differences, audiometric techniques and whether or not the size of the audiometer attenuator step was allowed for.
<table>
<thead>
<tr>
<th>Year</th>
<th>Author(s)</th>
<th>Source</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>El-Alami</td>
<td>Journal of the Society of Occupational Medicine 31: 27–30</td>
<td>Exposure to noise levels around 86 dB(A) produces no more abnormal audiograms than no exposure to potentially hazardous noise levels.</td>
</tr>
<tr>
<td>1982</td>
<td>Court of Appeal (Civil Division)</td>
<td><em>Robinson v British Rail Engineering</em>, No. 489 3 November</td>
<td>‘Decibel values’ are of little relevance to loss of amenity assessments.</td>
</tr>
<tr>
<td>1983</td>
<td>Fearn, Hanson</td>
<td>British Journal of Audiology 17: 87–90</td>
<td>Average hearing threshold levels measured by trained manual audiometer operators may differ by more than 6 to 10 dB.</td>
</tr>
<tr>
<td>1984</td>
<td>International Organization for Standardization</td>
<td>ISO 7029</td>
<td>Standard for threshold of hearing by air conduction as a function of age and sex for otologically normal persons (corresponds to NPL Ac 94).</td>
</tr>
<tr>
<td>1984</td>
<td>Robinson, Wilkins, Thyer, Lawes</td>
<td>ISVR Technical Report No. 126. University of Southampton</td>
<td>Auditory impairment and the onset of disability and handicap in noise-induced hearing loss (term ‘threshold of inability’ coined); an investigation specifically aimed at identifying the threshold of inability and its relation, on the one hand, to various audiological impairment measures and, on the other, to self-rated handicap (though, again, handicap is perhaps too strong a term to describe people’s hearing difficulties at the just-not-normal level). The resulting value of HTL, average at 1, 2 and 3 kHz, was found to be approximately 30 dB.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Publication</th>
<th>Medical/scientific relevance</th>
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</thead>
<tbody>
<tr>
<td>1985</td>
<td>Robinson</td>
<td>Annals of Occupational Hygiene 29: 477–93, at p. 492</td>
<td>A statistical test applied to audiograms to uncover causes other than occupational noise; audiometric picture of ONIHL also shown to be non-specific.</td>
</tr>
<tr>
<td>1987</td>
<td>Harrowven, Greener, Stephens</td>
<td>British Journal of Audiology 21: 209–19.</td>
<td>Individuals with noise-induced hearing losses can derive appreciable benefit from hearing aids provided that careful attention is given to the type of aid and the earmould engineering.</td>
</tr>
<tr>
<td>1987</td>
<td>Robinson</td>
<td>Noise Exposure and Hearing: A New Look at the Experimental Data. HSE Contract Research Report No. 1/1987. Health and Safety Executive</td>
<td>(a) The noise immission level concept is rejected. (b) If individuals live long enough they end up with the same threshold whether or not they had any previous hazardous occupational noise exposure: ‘the HTLs attained at the age of 60 or 65 years in the general population, when compared with those of noise-exposed persons of similar age, left little margin to account for the specific effects of noise’. (c) Reaffirms ‘threshold of inability’ as a ‘low fence’: ‘By coincidence this is the same numerical value as is used in BS5330 to describe the level above which a “handicap” is deemed to exist … 50% of the possessors of this level of hearing loss are still just within normal limits of hearing performance for young persons. Much lower “fences” have been canvassed by some authors, based on the level at which a test group shows a barely perceptible difference in performance from one with a smaller HTL. In the writer’s opinion, such estimates are a case of chasing shadows’ (at pp. 129–31).</td>
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</table>

Luxon CRC/JH 19/6/01 3:19 pm Page 328
<table>
<thead>
<tr>
<th>Year</th>
<th>Author(s)</th>
<th>Reference</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>HSE</td>
<td>The Noise at Work Regulations SI 1989 No. 1790(^{286})</td>
<td>For the control of hazardous occupational noise exposure; action to be taken depends on the measured noise exposure; the latter is given in terms of either the daily personal noise exposure (L_{EP,d}) or the peak sound pressure of the noise. Regulation 2 defines three action levels: first action level: (L_{EP,d}) of 85 dB(A); second action level: (L_{EP,d}) of 90 dB(A); peak action level: peak sound pressure 200 Pa (140 dB SPL).</td>
</tr>
<tr>
<td>1989</td>
<td>Saunders, Haggard</td>
<td>Ear and Hearing 10: 200–8</td>
<td>A condition recognized by Royal Air Force otologists is reported as ‘obscure auditory dysfunction’; hazardous noise exposure is not involved in causation.</td>
</tr>
<tr>
<td>1990</td>
<td>Schorn, Zwicker</td>
<td>Audiology 29: 8–20 at p. 19</td>
<td>Distortion measures (impaired frequency selectivity, impaired temporal resolution) are not specific for any one type of inner ear disorder.</td>
</tr>
<tr>
<td>1991</td>
<td>Stephens, Hétu</td>
<td>Audiology 30: 185–200</td>
<td>Clarifies distinction between I(^{287}), D(^{288}) and H(^{289}).</td>
</tr>
</tbody>
</table>

\(^{286}\) Based on EC Directive 86/188/EEC.  
\(^{287}\) Impairment.  
\(^{288}\) Disability.  
\(^{289}\) Handicap.
<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Publication</th>
<th>Medical/scientific relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>Robinson</td>
<td>British Journal of Audiology 25: 93–103</td>
<td>The concept of simple (linear) additivity (in decibels) of various factors is no longer tenable (what might be termed ‘compression’ occurs).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Author(s)</th>
<th>Title</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>Inter-Society Working Group on Hearing Disability</td>
<td>Assessment of Hearing Disability. London: Whurr</td>
<td>Proposes a method which, in spite of Court of Appeal comments in <em>Robinson v BREL</em>, is based (and uniquely so) on the decibel scale. The monograph makes clear (Paragraph 9.1.1) that <em>diagnosis</em> is first requirement in any compensation assessment and this is outside its terms of reference.</td>
</tr>
<tr>
<td>1993</td>
<td>Hinchcliffe</td>
<td>Revue de Laryngologie 114: 93–101</td>
<td>Age-associated changes in hearing threshold levels given by ISO 7029 and reflected in the MRC studies in the 1950s and in the 1980s (indicated by the MRC age/noise formula) are the same (as, on consideration, one would expect, because the MRC studies were conducted on random samples of the population, and the international standard was derived from the data so produced).</td>
</tr>
<tr>
<td>1993</td>
<td>Dobie</td>
<td>Medico-Legal Evaluation of Hearing Loss. New York: Van Nostrand Reinhold</td>
<td>A textbook from the USA which states, <em>inter alia</em>, that it is the experience of clinicians that those who have elevated hearing threshold levels for frequencies of around 6 kHz and above do not report problems in auditory communication.</td>
</tr>
<tr>
<td>1994</td>
<td>Lutman, Davis</td>
<td>Audiology 33: 327–50</td>
<td>Distributions of hearing threshold levels in populations exposed to noise; median thresholds of screened young adults in NSH were about 4 dB poorer than audiometric zero.</td>
</tr>
</tbody>
</table>

291 National Study of Hearing.
<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Publication</th>
<th>Medical/scientific relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>Hinchcliffe</td>
<td>Proceedings of 10th World Congress on Medical Law. Stier Group. Ramat Gan, Israel pp. 364–70</td>
<td>The numerical models used in medicolegal reports such as this are statistical, and not mathematical, models, i.e. they are not formulae to give precise values to expected hearing threshold levels.</td>
</tr>
<tr>
<td>1995</td>
<td>Davis</td>
<td>Hearing in Adults. London: Whurr</td>
<td>A one-thousand page publication that tabulates the data obtained from NSH.</td>
</tr>
<tr>
<td>1995</td>
<td>Haggard</td>
<td>Proceedings of the British Academic Conference on Otolaryngology</td>
<td>Director of the Medical Research Council’s Institute of Hearing Research reaffirms that socio-economic factors must be taken into account in hearing threshold measurements; there should now be little excuse for any British ENT specialist denying their existence.</td>
</tr>
<tr>
<td>1995</td>
<td>Zhao, Stephens, Sim</td>
<td>Proceedings of the Annual Conference of the British Society of Audiology</td>
<td>Supports the concept that King–Kopetzky syndrome is an auditory stress disorder.</td>
</tr>
<tr>
<td>1995</td>
<td>Hinchcliffe</td>
<td>Proceedings of International Advanced Research Workshop on Man and Environmental Noise, Turin, 12–13 Oct. Edizioni Minerva Medica</td>
<td>Indicated that one could reconcile reported differences between results of the National Study of Hearing and those from the 1950s by considering whether or not certain corrections (for audiometer attenuation step, learning) had been applied to threshold data, and remembering that audiometric reference zeros are based upon data gained on young adults. Pre-adult pathological factors could have produced an already-defective young adult threshold at, for example, 6 kHz. There is no evidence that the baseline of unsullied hearing, and its ageing, has changed in the UK over the</td>
</tr>
</tbody>
</table>
past 40 years. There is a need to define more precisely what a standard should represent, but continuing to change a standard means no fixed yardstick and we are back to the mediaeval ages. The method used by medical examiners to determine hearing thresholds and to report the audiometric data is similar to that used in the National Study of Hearing (NSH).

Indicates considerable variability in epidemiological data on occupational noise-induced hearing loss (ONIHL). Thus NIPTS at 4 kHz arising out of a 30-year daily exposure to 100 dB(A) for a man aged 50 years could be anywhere between 10 and 50 dB at the median, depending on the choice of data sets. If studies of ONIHL draw their noise-exposed subjects primarily from manual occupations, and their noise-free subjects from nonmanual occupations, there will be a confounding of the effects of noise and occupational group.

Argument advanced that if ‘every decibel counts’, why not ‘every attobel’ and why not every frequency? If negligent damage to even a single hair of an individual may attract damages, why not a single hair on a single hair cell? The answers to these questions will depend partly on where the courts will draw the line at de minimis. Nevertheless, medical examiners will need to be aware of the relevance and importance of such clinical conditions as the King–Kopetzky syndrome and labelling and bear in mind the experience of clinicians that people who have elevated hearing threshold levels for frequencies of around 6 kHz and above do not report problems in auditory communication.


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292 Noise induced permanent threshold shift – a better description than occupational noise-induced hearing loss as ‘hearing loss’ has a particular connotation and should not be used in conjunction with ‘decibels’.

293 Referred to by ENT surgeons as their ‘bible’.

294 10^-18 bels.

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Publication</th>
<th>Medical/scientific relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>Lutman, Qasem</td>
<td>Proceedings of Second European Conference on Protection Against Noise, 16–19 April, London</td>
<td>Common occurrence of 6 kHz notches is an artefact arising from a particular interaction between the IEC 303 coupler and the TDH-39 earphone.</td>
</tr>
<tr>
<td>1999</td>
<td>WHO</td>
<td>International classification of Impairments, Activities and Participation – A Manual of Dimensions of Disablement and Functioning 296</td>
<td>The successor to the 1980 WHO ICIDH. ‘Disabilities’ has been replaced by the activities (A) dimension; this classification is based solely on ‘activities’ of the person, which are actual performances. ‘Handicap’ has been formulated by participation. This has introduced a ‘positive’ connotation and conception of this dimension.</td>
</tr>
</tbody>
</table>

296 A revision of the WHO 1980 *International Classification of Impairments, Disabilities, and Handicaps* (ICIDH), which is now being subjected to systematic field trials and further consultations and which will come into effect in 1999.
Part V
Chronology of Publications Relating Tinnitus to Noise Exposure
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<table>
<thead>
<tr>
<th>Author</th>
<th>Pub</th>
<th>Geog</th>
<th>Occupation</th>
<th>Sampling</th>
<th>Num</th>
<th>Ages</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roosa</td>
<td>1874</td>
<td>USA</td>
<td>Boilermakers</td>
<td>?</td>
<td>8</td>
<td>22–66</td>
<td>Consistent with Barr’s findings.</td>
</tr>
<tr>
<td>Brunner</td>
<td>1880</td>
<td>Zürich</td>
<td>A lady</td>
<td>Patient</td>
<td>1</td>
<td>36</td>
<td>Vivid case history of effect of acute acoustic trauma (gunfire).</td>
</tr>
<tr>
<td>Holt</td>
<td>1882</td>
<td>Maine</td>
<td>Boilermakers</td>
<td>Workforce</td>
<td>40</td>
<td>19–62</td>
<td>No tinnitus.</td>
</tr>
<tr>
<td>McBride</td>
<td>1882</td>
<td>Scotland</td>
<td>Various</td>
<td>Patients c/o tinnitus</td>
<td>?</td>
<td>all</td>
<td>Despite the prevalence of ONIHL in the 19th century, tinnitus due to occupational noise exposure did not appear to have been listed in causes of tinnitus among patients at that time.</td>
</tr>
<tr>
<td>Barr</td>
<td>1886</td>
<td>Glasgow</td>
<td>Boilermakers</td>
<td>Workforce</td>
<td>100</td>
<td>17–67</td>
<td>Tinnitus occurs early, if at all, in the course of hazardous occupational noise exposure and is not a prominent feature of hazardous occupational noise exposure.</td>
</tr>
<tr>
<td>Rodger</td>
<td>1915</td>
<td>Leith</td>
<td>Boilermakers</td>
<td>Workforce</td>
<td>44+4</td>
<td>Working</td>
<td>Concurs with Barr.</td>
</tr>
</tbody>
</table>

297 Year of publication of report.
298 Sample size.
<table>
<thead>
<tr>
<th>Author</th>
<th>Pub</th>
<th>Geog</th>
<th>Occupation</th>
<th>Sampling</th>
<th>Num</th>
<th>Ages</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacher</td>
<td>1927</td>
<td>Leningrad</td>
<td>Boilermakers</td>
<td>Workforce</td>
<td>297</td>
<td>Working</td>
<td>High prevalence of both tinnitus and dizziness.</td>
</tr>
<tr>
<td>McKelvie</td>
<td>1933</td>
<td>Lancashire</td>
<td>Weavers</td>
<td>Workforce</td>
<td>1011</td>
<td>Working</td>
<td>No tinnitus.</td>
</tr>
<tr>
<td></td>
<td>1937</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larsen</td>
<td>1939</td>
<td>Odense</td>
<td>Shipyard and machine factory</td>
<td>Workforce</td>
<td>250</td>
<td>19–66</td>
<td>Reported prevalence of tinnitus depends upon method of eliciting a</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>response.</td>
</tr>
<tr>
<td>Goldner</td>
<td>1945</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Review of literature on occupational noise-induced hearing loss; no</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>mention of tinnitus.</td>
</tr>
<tr>
<td>Weiss</td>
<td>1946</td>
<td>USA</td>
<td>Military</td>
<td>?</td>
<td>33</td>
<td>&gt;21;&lt;60</td>
<td>Gunfire.</td>
</tr>
<tr>
<td>Siirala,</td>
<td>1948</td>
<td>Finland</td>
<td>Shipyard</td>
<td>Workforce</td>
<td>303</td>
<td>&gt;21;&lt;60</td>
<td>Workers exposed to hazardous noise levels but majority were ex-military.</td>
</tr>
<tr>
<td>Lahikainen</td>
<td></td>
<td></td>
<td>with hearing problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heller,</td>
<td>1953</td>
<td>USA</td>
<td>Various</td>
<td>Patients,</td>
<td>80</td>
<td>Adults</td>
<td>Everyone has tinnitus.</td>
</tr>
<tr>
<td>Bergman</td>
<td></td>
<td></td>
<td></td>
<td>hospital staff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Author</td>
<td>Year</td>
<td>Country</td>
<td>Type</td>
<td>Number</td>
<td>Sector</td>
<td>Description</td>
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</table>
| Goldner   | 1953 | USA     | Shipyard Workers | 403 | Working | Tinnitus is ‘often more disturbing than the deafness. In some few cases the extent of the tinnitus was disabling, necessitating a change of occupation’. However, the tinnitus ‘tended to get less bothersome after years of exposure’.
| Venters   | 1953 | GB      | Various Patients | 254 | All     | Only one (a boilermaker) of his 254 clinical cases of tinnitus could be attributed to occupational noise damage to the hearing.
| Dickson²⁹⁹ | 1954 |         |           |       |         | Having reviewed the literature on occupational noise-induced hearing loss for a major textbook on occupational medicine, and incorporating his own vast personal experiences and those of the members of his department, mention of occupational noise-induced tinnitus is conspicuous by its absence; mention of noise-induced tinnitus is restricted to three words and two numbers in a chapter that comprised well over 10 000 words; moreover, even that mention of noise-induced tinnitus is in respect of gunfire. |

²⁹⁹ The most senior otolaryngologist in the Royal Air Force at that time.
<table>
<thead>
<tr>
<th>Author</th>
<th>Pub</th>
<th>Geog</th>
<th>Occupation</th>
<th>Sampling</th>
<th>Num</th>
<th>Ages</th>
<th>Comment</th>
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<tbody>
<tr>
<td>Hinchcliffe</td>
<td>1961</td>
<td>Scotland</td>
<td>Various</td>
<td>Random</td>
<td>381</td>
<td>18–74</td>
<td>20–40% (depending on age) of general population have experienced tinnitus.</td>
</tr>
<tr>
<td>Wilson Report</td>
<td>1963</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Covers the broad problem of noise, particularly its psychological effects, but no mention of tinnitus.</td>
</tr>
<tr>
<td>Burns, Robinson</td>
<td>1970</td>
<td>UK</td>
<td>Noise-exposed</td>
<td>Volunteer</td>
<td>759</td>
<td>Working</td>
<td>Tinnitus not reported as a problem.</td>
</tr>
<tr>
<td>Atherley, Noble</td>
<td>1971</td>
<td>England</td>
<td>Dropforgers</td>
<td>Random</td>
<td>18 (38)</td>
<td>36–53</td>
<td>&lt;10% experienced tinnitus but this was not troublesome.</td>
</tr>
<tr>
<td>Occupation Deafness</td>
<td>1973</td>
<td>UK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The evidence presented by the British Association of Otolaryngologists was that tinnitus was not a common feature of noise-induced deafness (paragraph 24). To the best of my knowledge subsequent reviews of the DSS scheme, up to and including Cmd 1245 of 1990, have not</td>
</tr>
</tbody>
</table>

300 Presumably it was for this reason that a Professor of Psychological Medicine was appointed as Deputy Chairman of the Committee.
301 Even though the Committee received evidence from the British Association of the Hard of Hearing, BAO, BMA, Director of the MRC Research Unit on Deafness, and the TUC.
302 Cmd 5461. London: HMSO.
303 Prepared by DL Chadwick, RRA Coles, EDD Dickson, PF King and IG Robin.
Publications relating Tinnitus to Noise Exposure

<table>
<thead>
<tr>
<th>Author, Location, Year</th>
<th>Country</th>
<th>Study Type</th>
<th>Sample Description</th>
<th>Results</th>
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</thead>
<tbody>
<tr>
<td>Taylor 1979 Scotland</td>
<td></td>
<td>?</td>
<td>?</td>
<td>Anecdotal: ‘in many cases the symptom arises long after exposure to excessive noise has ceased’.</td>
</tr>
<tr>
<td>Coles, Davis, Haggard</td>
<td>UK</td>
<td>Various</td>
<td>Random (of UK population)</td>
<td>Vast majority of people who have tinnitus do not complain about it.</td>
</tr>
<tr>
<td>Cahani, Paul, Shahar</td>
<td>Israel</td>
<td>Military</td>
<td>Male patients</td>
<td>Gunfire.</td>
</tr>
<tr>
<td>Meikle, Taylor-Walsh</td>
<td>USA</td>
<td>Mixed</td>
<td>Tinnitus clinic patients</td>
<td>‘80% of the men had had exposure to loud sounds’; but it is not clear what ‘exposure to loud sounds’ meant; apparently based upon a questionnaire and actual questions were not included in the publication; no control population. (Class 4 evidence.)</td>
</tr>
</tbody>
</table>

sought to change this statement even though the review committee has considered tinnitus on one or several occasions.
<table>
<thead>
<tr>
<th>Author</th>
<th>Pub</th>
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<th>Num</th>
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<th>Comment</th>
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</thead>
<tbody>
<tr>
<td>Chung, Gannon, Mason</td>
<td>1984</td>
<td>British Columbia</td>
<td>Workers exposed to 85 dB(A) or more</td>
<td>All in the Province</td>
<td>30000</td>
<td>18–65 (probably)</td>
<td>Likelihood of a worker answering in the affirmative to the question ‘do you now have ringing in your ears?’ increases with the level of the threshold of hearing but for no hearing threshold level does it reach a probability of ‘more likely than not’; overall prevalence (6.6%) of admitted tinnitus in these noise workers is less than that for the general population of the UK or the USA; no indication that any worker had troublesome tinnitus.</td>
</tr>
<tr>
<td>Axelsson, Sandh</td>
<td>1985</td>
<td>Sweden</td>
<td>Various</td>
<td>Male patients 94 with noise-induced hearing loss</td>
<td>18–35</td>
<td>80–100% had served in military.</td>
<td></td>
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<tr>
<td>Hazell</td>
<td>1985</td>
<td>UK</td>
<td>Various</td>
<td>Patients 472</td>
<td>&gt; 20; &lt; 90</td>
<td>‘noise induced hearing loss and acoustic trauma’ was diagnosis in 27% of the patients.</td>
<td></td>
</tr>
</tbody>
</table>

304 Coles, Davis and Haggard (1981).
305 Singer, Tomerlin, Smith and Schrier (1982).
306 But his ideas have now changed radically regarding tinnitus and its causation.
307 Therefore a case series (Class 4 evidence).
<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Location</th>
<th>Group</th>
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<tr>
<td>ISVR</td>
<td>1986</td>
<td></td>
<td></td>
<td>‘The incidence of serious disturbance among workers employed in heavy industry seems rather less than in the population as a whole.’</td>
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<tr>
<td>Alberti</td>
<td>1987</td>
<td>Ontario</td>
<td>Mainly hard rock miners Claimants</td>
<td>Tinnitus ‘was present in 58% of claimants, and was rated as a major problem in 19%’.</td>
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<tr>
<td>McShane</td>
<td>1988</td>
<td>Ontario</td>
<td>Noise hazardous Claimants Adults</td>
<td>Features of tinnitus in this select group (claimants) were different from those of tinnitus seen in other groups. ‘The reason for these differences is unclear, though the possibility of financial motivation by some claimants is raised.’</td>
</tr>
<tr>
<td>Axelsson, Barrenäs</td>
<td>1991</td>
<td>Göteborg</td>
<td>Mixed Clinic patients</td>
<td>Prevalence of ‘previous occupational noise exposure’ in tinnitus-clinic patients was 33% (a case series), i.e. what the epidemiologist refers to as Class 4 evidence (lowest on the scale 1 to 4).</td>
</tr>
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</table>

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308 Clinical Audiology Course Notes (edited by Professor DW Robinson).
309 Referring to tinnitus.
<table>
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<tr>
<th>Author</th>
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<tr>
<td>Rosenhall, Karlsson</td>
<td>1991</td>
<td>Göteborg</td>
<td>Retired</td>
<td>Random</td>
<td>1098</td>
<td>70–79</td>
<td>Did not show that disturbing tinnitus was connected to previous noise exposure.</td>
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<td>Davis, Coles, Smith, Spencer</td>
<td>1992</td>
<td>UK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hazardous occupational noise exposure not a tinnitus risk per se: the Medical Research Council’s National Study of Hearing concluded that potentially noise hazardous employment did not constitute a particular risk for the development of tinnitus.</td>
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<tr>
<td>McBride</td>
<td>1993</td>
<td>Staffs</td>
<td>Coal miners</td>
<td>Colliery</td>
<td>189</td>
<td>Working</td>
<td>Unable to show that continuous tinnitus related to hearing loss.</td>
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<tr>
<td>title</td>
<td>Noise and Hearing. Volume 1, Readings for the Medical Examiner: Assessing Cases of Occupational Noise-induced Hearing Loss Noise and Hearing; V. 1</td>
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<tr>
<td>author</td>
<td>Hinchcliffe, Ronald.; Luxon, Linda M.; Williams, Richard G.</td>
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