It is estimated that 5-10% of patients with significant hearing loss do not get satisfactory help with a hearing aid. This means that in Australia there are about 5,000-10,000 people who need further treatment. Furthermore, a large number of these patients are born deaf and their proper management is critical if they are going to develop adequate speech and language. If these patients are going to perceive speech, the speech must be broken down into signals that can be used to stimulate the residual hearing, excite the auditory nerve fibres by electrical stimulation or stimulate another sensory system such as vision or the skin senses. These alternatives offer real hope for the patient with severe sensori-neural deafness as there is a great deal of redundancy in the speech signal. This is illustrated in Fig. 1 which shows the raw signal obtained on a cathode ray oscilloscope for the word ‘ear’. It can be seen that there is an overall waveform envelope which is now thought to be quite important in speech perception. Inside the speech waveform there are waves of many shapes and sizes. Far too many for your eye to detect at a glance, and indeed too many for your ear to perceive. In fact, when you hear phonemes and words your brain only picks up key signals.

For example, when the words bay, day and gay are spoken the only difference is in the first consonant. These consonants are called plosives and they are distinguished almost entirely by whether the second formant is a rising or a falling one. This is illustrated in Fig. 2. This shows the first and second formants for the plosives “b”, “d” and “g”. The formant is simply a term used for the concentration of sound energy at different frequencies, and you can see that for “b” there is a rising second formant, for “g” a falling second formant, and “d” has a fairly flat second formant.

Not all consonants have the same type of key signal as the one described. Fricatives like “s”, “sh”, “h”, “l” are another group, and they are perceived on the basis of the energy concentrations of the white noise. For example, with the “s” sound the noise energy...
is concentrated above 4000 Hz, whereas with “sh” it is concentrated at 2500 Hz.

Prosthetic devices are designed to pick out key signals from speech, and to present them in an appropriate way to the patient. The first prosthetic device to be discussed is the speech transposition aid. It works by taking the higher frequencies from the speech signal, and making them into lower ones and also compressing them together. The advantage of this device is that it uses residual low frequency hearing. The main disadvantage is that when you take the key signals the brain uses for recognizing phonemes and words and make them into something else it is confusing, as there are too few nerves in the low frequency area to handle all the information.

The next prosthetic device to be discussed is the visual vocoder. This is seen in Fig. 3. The patient wears glasses, and small lights are attached around the periphery. When someone speaks to the patient their speech is analyzed by a special electronic device, and the key signals in speech presented as different patterns of light stimulation. The main advantage of this device is that it will help the patient with lip reading. For example, the words pay and bay look the same on the lips, and cannot be distinguished without hearing even if the patient is good at lip reading. The visual vocoder, however, picks out the key signal and presents this as a pattern of lights on the glasses which the patient learns to recognise. The visual vocoder, however, has two main disadvantages. Firstly, it cannot be used for the deaf blind child, and although the problem is becoming less with better control of rubella, it will still remain, as it can be produced by other conditions such as Ushers syndrome. The second disadvantage is that the need to concentrate on the pattern of lights may reduce the attention given to the movement of the lips.

Possibly a more promising device is the tactile vocoder. The tactile vocoder can be used in one of two ways: Firstly, it can be used to produce a feeling of vibration in the skin receptors. A promising device for the purpose is the Optacon which is used to help blind children recognise letters. In Fig. 4 we see an Optacon. It is usually applied to the fingertips and can stimulate a number of points with the small vibrators. Work is now being done to adapt this Optacon for deaf patients. In the past, these mechanical vibrators have not been very satisfactory in helping deaf children perceive speech, as a static signal has been used, and the patients rapidly adapt to the pattern of vibration. Now a moving pattern is being used to represent speech, and the results are much more promising. Furthermore, with repeated use, the patient comes to perceive the tactile representation of speech as an entirely separate sensation which is helpful in the perception of language. This change in the perceptual qualities of the tactile stimulus has been well demonstrated in the visual system. Patients who have an array of electrodes on their back connected to a television camera which does their seeing for them, receive a sensation which becomes so real that when the camera is zoomed, they will actually duck to avoid the approaching object. The main disadvantages of the Optacon are that it has
to be used on the fingertips and this restricts
the hand movement of the child, the
mechanical vibrators are easily damaged, and
there is no capacity to vary the intensity of
stimulation for each vibrator.

Finally, a multiple-electrode cochlear im-
plant can be used for patients with severe
sensori-neural hearing loss and is shown in
Fig. 6. This receiver/stimulator is placed in
the mastoid bone, and connected to a num-
ber of electrodes which have been implanted
close to auditory nerve fibres. Power and
coded information about speech is transmit-
ted to the receiver through the skin by a
form of radiotelemetry. The main advantage
of the cochlear implant is that it uses the
auditory nervous system which has been de-
dsigned in an appropriate way to detect the
key signals of speech. There is increasing
evidence from basic research studies to show
that the auditory system has a special ability
to code and decode the frequency transitions
of, say, the second formant, which as we
have seen is the key signal in the percep-
tion of plosives. These transitions cannot be
easily detected by the visual and tactile sys-
tems. Furthermore, electrical stimulation of
the auditory nervous system is much more
likely to produce an acoustic sensation, than
stimulation of the other sensory systems.
The main disadvantages of a cochlear im-
plant are the usual ones of any ear surgery,
and the fact that the implant receiver and
electrode may have a limited life, and require
further surgery for their replacement.

In deciding eventually what type of pros-
thetic device is most suitable for a particular
patient, a number of factors need to be con-
sidered. At the present stage of develop-
ment a tactile vocoder is useful for infants
and young children. A visual vocoder is of
more potential value as an aid for a child
or adult who needs help with speech or lip
reading. At the moment, on the other hand,
a cochlear implant is best reserved for adults.
Furthermore, they should have near total
deafness as shown on the pure tone audio-
gram, speech comprehension should be poor,
there should be no evidence of middle ear
or central nervous system disease, and they
should be psychologically stable and be able
to participate in a prolonged post-operative
test programme.
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