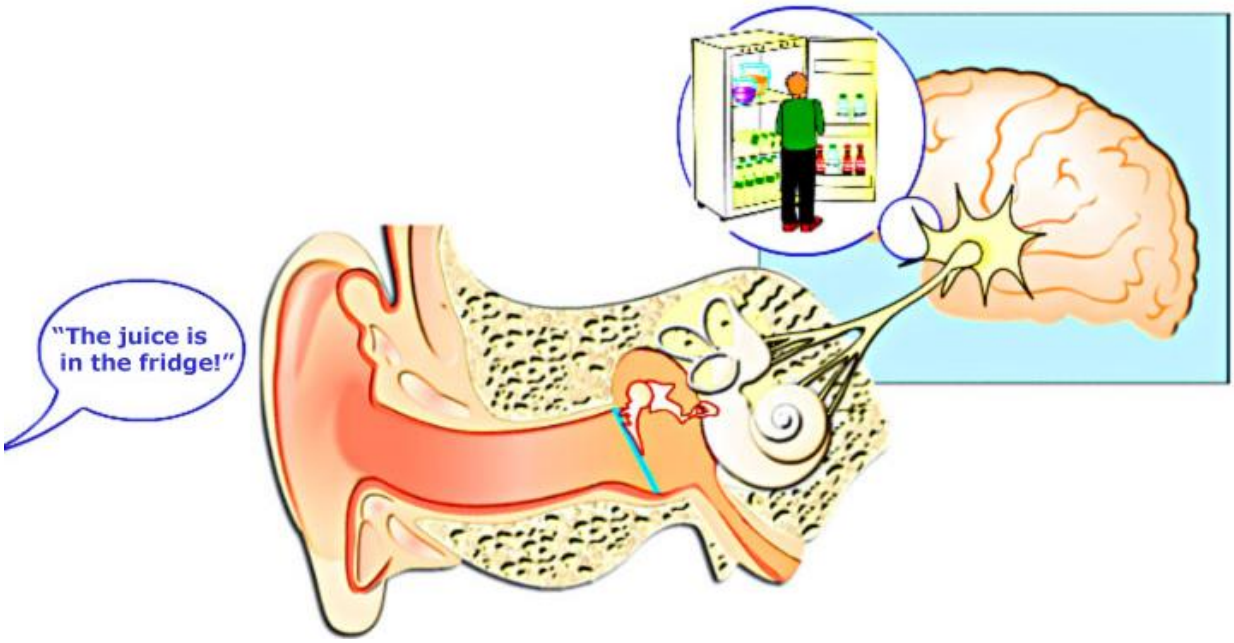
Hear, recognize and understand speech

In the following, it is not the anatomical aspects that are the focus of attention. Instead of the question “What happens where in the ear and the brain?”, we are more interested in the logically functional sequence of processing.
Let us assume the child is in its room; its mother puts her head round the door and says “The juice is in the fridge!”
During the hearing process, the sound waves go through several stages, during which they are converted into neuronal information, the language of the brain.



Sound vibrations are converted into nerve impulses

- Collection in the outer ear (pinna).
- Amplification of the sound via beaming and resonance in the ear canal.
- The sound waves cause the eardrum to vibrate.
- The vibrations of the eardrum stimulate the ossicles, which then start to vibrate.
- At the same time, there is amplification because of the lever effect and concentration of pressure!
- The movement of the stapes generates a traveling wave through the fluid in the inner ear.
- The traveling wave causes relative movement of the basilar membrane against the tectorial membrane in the organ of Corti.
- The tectorial membrane stimulates the hair cells, causing them to bend.
- The sensory cells generate electrical impulses.
- The impulses are conveyed via the auditory nerve (nerve VIII) to the brain.

Nerve impulses enter the brain and undergo initial processing

The impulses sent by the sensory cells are now in the brain, in code. High volume of a sound means that the nerve signal is repeated with a high impulse frequency. The frequency of a tone is recognized according to where it was produced in the cochlea, the high tones being picked up at the base of the cochlea, and the low tones at the apex. After the impulse has entered the brain via

the cochlear nucleus, it makes its way to the older part of the brain – from the evolutionary standpoint – namely, the brain stem.

Coordination with other sensory impressions

Now, coordination with other sensory impressions takes place. The child, for example, has felt the current of air when the door opened (sense of touch), it has heard a noise (subconscious hearing), looked up towards the door and recognized its mother (sense of sight). If emotions do not now take over, the brain automatically switches over to conscious hearing, in the sense of speech recognition.

Emotional processing

The speech signal also is always received in the limbic area of the brain. This area reacts via reflex unconsciously (through the autonomic nervous system) and evaluates speech from the emotional standpoint. For example, if the child recognizes from its mother's tone of voice that she is moaning again (“Have you done your homework yet?”), it would perhaps react by reflex action and more or less “switch off”. The content of the sentence might not even be actually heard.
If we disregard the emotional component – which is actually superfluous when it comes to understanding speech – the brain actually works on three levels, when understanding what it hears.

Sound analysis and pattern recognition in the auditory centre

The signal ultimately arrives in the cortex of the brain, more specifically, the “auditory cortex”.

Checking for time, rhythm and melody

Based on this formal framework, the brain very quickly recognizes that it is speech that it is hearing and not a sound, noise, music, or singing.

Sound analysis and synthesis of the phonemes, syllables, and words

Now, sound patterns are recognized using a sort of “Scrabble” technique. After comparison with things in its memory stores, the brain combines these sounds to phonemes, syllables, and, ultimately, words. If that works, and there is a word that matches in the memory store, the brain then moves on to the next word (incidentally, these are mechanisms similar to speech recognition software, although the brain is much more subtle and elemental).

Matching of word meanings and sense-analysis of sentences

Up to this stage, the process of recognition is relatively mechanical. Now the intelligent areas of the brain have to join in: for example, the long-term memory, a sort of encyclopedia, the speech centre, and various associated areas for sense analysis. Modern brain research has shown that hearing does not just take place in the auditory centre. In the hearing process – as in the visual process as well – the intelligent areas of the brain are used together, and parallel to each other, by all the senses.
The meaning of the words is now recognized, the sentence construction is analyzed, and the sentence evaluated. This is where the human ability to think in abstract terms and make abstract conclusions plays a role. Whether the child actually has a mental picture of the juice in the refrigerator or not, it knows where to look for it. The idea that a human being thinks in concrete images is fairly

naive. First of all, that would mean that people born blind could not think. Secondly, there are enough abstract contexts in the world of science, philosophy, religion, and society that can be classified at best as “Symbols as reminders” – for example, an old man with a long white beard is seen by a lot of people as a visual symbol for God.