PROCESSES IN BIOLOGICAL HEARING

Synopsis 26Feb05

This is the work of an analyst from outside the immediate field of hearing.

When attempting to compare the state of the art in hearing with the recent advances in the field of vision, he was astounded to find there was no comprehensive description of how hearing was performed in the biological sphere. While considerable material was available on the morphology of both the peripheral and central portions of the hearing modality of the nervous system, there was virtually nothing available explaining how the hearing system worked (except conceptually). The literature of the last fifty years is sprinkled with comments about the lack of a coherent explanation of how hearing is accomplished by a variety of experienced leaders in the hearing research field.

This work is designed to fill the void concerning how hearing is accomplished. The overall project consists of two parts; the creation of a large comprehensive and definitive manuscript on hearing (that is economically impractical to publish in hard copy, and a more manageable printed text abstracting the highlights of the broader manuscript. It is hoped that this printed version will provide a comprehensive guide to the overall mechanism of hearing and answer most of the crucial questions concerning the morphology, physiology and circuit operation of the hearing modality. Simultaneously, it will act as a guide to the broader manuscript that is available over the internet.

The modality of hearing cannot be understood based on the limited literature available in the printed journals and pedagogically oriented texts. Additional material is required that has only become available during the last five years. A major source of this material is a parallel effort by the same analyst developing a similar understanding of the modality of biological vision. That effort introduced a large number of new findings that together introduced a major paradigm shift in thinking. Many of those same findings are important to the understanding of hearing. The most crucial finding was the discovery of the active electrolytic liquid crystalline semiconductor device at the heart of all neurons, the Activa. Discovery of the Activa opened up new avenues in biological research. First, it provided the tool needed to understand the detailed internal operation of both the neuron and the synapse. Both the neuron and the synapse are shown to be active electrolytic semiconductor devices. Second, the existence of the Activa showed how the neuron operated metabolically. The housekeeping activity of the soma was shown to be almost entirely separate from the neural elements of the cell involved in signaling. This separation even extends to the food used by the cell. The housekeeping portion, centered on the nucleus and mitochondria operate aerobically, rely upon the oxidation of glucose. However, the neural portion does not. The neural portion operates anaerobically by relying on the decomposition of glutamic acid.

Another major change required to understand hearing was to recognize the great divide between the neurons involved in communications by phasic means (relying upon action potentials) and the much larger population (estimated at 99%) and more important class of neurons involved in communications by analog means. Following this realization, it is possible to subdivide the neural portion of the hearing modality into a series of easily identifiable “engines” connected by a large number of neural signaling channels grouped into nerves and commissure.

While the general acousto-mechanical operation of hearing has been well understood since the 1930's, there has been a lack of detailed understanding because the concept of the impedance of mechanical structures has not been widely applied. This has led to inconsistencies and controversy concerning various theories of how the acousto-mechanical elements operate. A comprehensive review of this work provides a single set of performance parameters that can be used in future investigations.

The method of acousto-mechanical energy to electrical signal conversion used in hearing has been a major unknown up to this time. This problem has been due in large part to the practice within the relatively closed hearing research community to rely upon incremental advances applied to the conceptual theories of icons of an earlier era. Current texts continue to herald the work of Helmholtz in the middle 1800's, Fletcher, et. al. in the 1930's and von Bekesy up through the 1960's. Unfortunately, these great men defined concepts based on the technologies of their day. They were unable to provide theoretical frameworks based on mechanisms used in the biological kingdom that were unknown to human science. Subsequent reliance upon these largely conceptual theories has slowed progress in hearing greatly. A particular problem has been the failure of the community to introduce the scientific knowledge garnered during the 1960-90's in other fields into the field of hearing research. Recognition of the Activa as a semiconductor device, from the field of electronics, allows understanding of the neural signaling system. Recognition of the surface acoustic wave filter, also from electronics, allows understanding of the operation of the cochlea.

Up until this work, the operation of the cochlea has focused on a particular element of a complex structure within the cochlea known generally as the cochlear partition. The most obvious portion of this structure, visible with a light microscope, is the basilar membrane. Because of its presence, Helmholtz, et. al. settled on this element as the key to understanding the transduction process in hearing. They saw the basilar membrane as capable of some form of one-dimensional frequency selection mechanism. Later, von Bekesy championed this same element even though multiple objections to such a role for the basilar membrane were accumulating. Wever summarized these problems in the 1970's. Wever's list was troubling because it was convincing. However, no substantial replacement theory was offered. Since the objections he cited did not lead to a paradigm shift in thinking, various incrementally different alternate theories arose. None of these have achieved significant acceptance. His list will be reviewed and expanded in this work to address even the incrementally advanced theories.

The most crucial problem can be associated with the famous Razor of Occam. Both earlier and current theories relating to the basilar membrane do not provide any explanation for the presence of, or functional mission of, the two distinct rows of sensory neurons along the cochlear partition known as the inner and outer hair cells. Von Bekesy, et. al. used the razor to cut too thin.

This work develops the fact that the two critical acousto-mechanical elements of the cochlear membrane are Hensen's Stripe and the gelatinous surface of the tectorial membrane facing the inner and outer hair cells. When an analyst of some experience looks globally at the cochlear partition, it becomes immediately obvious that a two-dimensional surface acoustic wave filter is at the core of the acousto-mechanical-to-electrical transduction problem. It becomes a matter of documenting the details. This activity is performed in considerable detail in this work.

The breakthroughs described above allow for a much clearer understanding of the interconnection of the multitude of individual signal processing engines found in the auditory system. This understanding allows a subsequent description of the overall performance requirements of the hearing modality. While the detailed signal processing and signal manipulation capabilities associated with the analog neurons of these engines have not been documented previously, it becomes possible to outline the major tasks of many of the engines of the central nervous system for the first time. This is done in the context of a series of major operating modes, alarm, awareness, analysis, cognition and response. The result is a significant framework upon which a broad applied research program within the community can be based.

The author is looking forward to answering any questions from researchers currently active in the hearing community, and particularly any newer entrants into the community who will assume the task of moving ahead into the applied research sphere. The World Wide Web offers the opportunity for a much wider dialog than ever before. The website www.hearingresearch.net includes both a comment facility and a chat room in support of such discussions. It is open to all and will be supervised to

optimize the value to all.