CONFERENCE

Comparative studies on the transduction mechanisms and its controls in mechanoreceptors

Okazaki, Japan

7th and 8th December, 1979

The conference, held at the National Institute for Physiological Sciences in Okazaki, on December 7 ~ 8, 1979, is one of the meeting programs of the Institute. The institute is part of the National Center of Biological Sciences, which was established in 1977, and is to some extent modelled after the National Institute of Health in U.S.A.

The program of the conference was designed to discuss the transduction mechanism and its nervous control in mechano-receptors, in which hair cells in inner ear and lateral-line organ, cutaneous touch receptor and stretch receptor in muscle were included. Nine papers given in this meeting focused on the relationship between ionic permeability in the transduce membrane and its electron-microscopic structure in the different kinds of mechano-receptors. The program was organized by Fumio Ito.

The concept of mechano-transduction was derived thirty years ago. Katz,[1] recording the electrical responses from the sensory nerve fiber in the vicinity of the muscle spindle of frog, showed that the impulse discharge was generated by a graded and sustained depolarization of the sensory terminals. The first intracellular study of electrical responses of mechano-receptors was performed by Eyzaguirre and Kuffler[2] on the stretch receptor of lobster and crayfish. In agreement with the results obtained by Katz,[1] it was found that sensory stimuli produce depolarization of the cell membrane and that nerve impulses arise if the depolarization attains sufficient amplitude (a threshold for encoder). This depolarization became known as the "generator potential" (a term introduced by Bernhard and Granit[3]) or "receptor potential" (Davis[4]). Pioneering discussions on the production of the receptor potential have been made by Katz,[1] e.g., a capacitance change, chemical changes or permeability changes may be caused by the deformation of the membrane.

The following four hypothesis have been based on the view of Thurm[5] who have noticed the structural and functional characteristics on the energy supply in mechano-transduction. (1) The confrontation of a marked "anisotropy" of the receptor cell terminals to the higher "isotropy" of the basic organization of nerve axons is associated with differences in the functional basis of these cellular regions. Since the receptor current is generated in a terminal structure, the current circuit is locally fixed, in contrast to the local circuit which move along an axon. Whereas in an unmyelinated axon every membrane area becomes the site of current inflow as well as of outflow successively, in a receptor terminal one area is subject only to the inflow, the other area only to the outflow of the net current. Importance of structural and functional asymmetries in sensory transduction within receptor cell has also been pointed out in the frog muscle spindle by Ito *et al.*[6] (2) The sensory cells of most types are part of epithelia which separate two liquid-filled spaces. The

external medium can differ very much from the inter-cellular medium, just as for instance fresh water does or the cochlear "endolymph" which has a K^+/Na^+-ratio similar to the intracellular K^+/Na^+-ratio. Alexeev[7] found changes of K^+-concentration in the intra-capsular space of frog muscle spindle to be seven times slower than in the external solution, suggesting that the outer capsule of the frog muscle spindle acts as a diffusion barrier for potassium ions. High potassium contents in Pacinian corpuscle fluid have also been observed by Ilyinsky *et al.*[8] (3) Thurm[5] found the ratio of the density of mitochondria to be about 10 times higher in receptive regions in sinus hair cells of mini-pig than in axons of the same diameter. The mitochondria contain dense intramitochondrial granules which are known in other cells to contain concentrations of divalent cations (Lehninger[9]). This leads us to the fourth hypothesis. (4) Sodium channels of the axonal membrane along the sensory nerve may be replaced by calcium channels at the terminal membrane of the mechanoreceptor. The calcium channels may play a role of transduction.

On the base of above mentioned hypothesis, some important discussions were made in this meeting. Yoshioka developed a new method for measuring the membrane potential of small cells as auditory inner-hair cells of mammals, by means of [3H]-triphenyl methyl phosphonium ions. An important morphological basis on the function of mechano-receptors was given by Hama, who showed a special gap-junction between hair cells in the auditory and lateral-line organs. Yanagisawa showed a common functional property between auditory and lateral-line receptors in different ionic environments. The study on the integrative control function of brain stem to cochlear neuron by Murata was of interesting on the point that an amplifier mechanism in the mechano-reception is controled by the efferent system. Taniguchi studied HRP morphology of the efferent axon innervating the inner-hair cells, supporting the study of Murata. Evidence that considerably low resting potential of the inner-hair cells is due to the characteristic ionic environments was shown by Tanaka. Hisada presented an interesting morphological aspect of the mechanical transformer in crayfish tactile receptors. By means of newly developed technique, Uehara and Desaki showed scanning microscopic photographs of end-plate and muscle spindles in the frog skeletal muscles, by which the members of this conference were facilitated their scientic curiocity. Ito proposed a model of mechano-transduction in the frog muscle spindle. The model, like the IVth hypothesis mentioned above, represented that calcium channels may play a role as a transduction and also as an amplifier in transmission from the the transduction to encoding.

The success of this meeting was due to the hospitality and valuable suggestions of the Center staff, the president Yasuji Katsuki, the Dean Professor Kouji Uchizono and Professor Shun-ichi Yamagishi.

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Gap junctions between hair cells and supporting cells in the goldfish saccular macula. A freeze fracture study.

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Introduction

Gap junctions have been considered to be responsible for cell-cell communization and are found where electrical coupling or metabolic cooperation is present.[1,2] Many extensive gap junctions have been found between adjacent supporting cells in some acousticovestibular sensory receptors.[3] In the present study, gap junctions are found between hair cells and supporting cells in the goldfish saccular macula. The functional significance of these gap junctions is discussed.

Materials and methods

Common goldfishes, about 10 cm in body length, were used. Saccular maculae were dissected out after decapitation without anesthesia. Specimens were fixed by immersion in 3 % glutaraldehyde and 0.1 M cacodylate buffer, pH 7.3, for one hour and cryoprotected in 25 % glycerol in the same buffer for two hours on ice. Specimens were frozen by immersion in Freon 12 at −155°C. Freeze fracture replicas were prepared using a Balzers freeze fracture device at −115°C.

Result

Indentations formed by nerve terminals are found on the basal half of the receptor cell. Many small gap junctions are observed outside the indentation on the receptor cell membrane. They are probably formed between the receptor cell and supporting cell since the baso-lateral surface of the receptor cell is covered by supporting cells except for the region attached to the nerve terminal. They are usually small and may consist of only 11 particles (Fig. 1). However, rather large ones consisting of over hundred particles are occasionally encountered (Fig. 2). The diameter of constituent particles is 8.77 nm ± 0.50 nm which is smaller than that of supporting cell-supporting cell gap junctions, 9.50 nm ± 0.63 nm