The effects of modification of extracellular concentrations of \( \text{Ca}^{2+} \) and \( \text{Cl}^- \) on mechano-perception were studied in internodal cells of \textit{Chara corallina}. Cells were stimulated by dropping a piece of glass tubing on them, and the resulting receptor potentials and action potentials were analyzed. When the \( \text{Ca}^{2+} \) concentration was extremely lowered by adding EGTA, the amplitudes of both receptor potentials and action potentials were attenuated, suggesting the involvement of \( \text{Ca}^{2+} \) channels. However, the possibility remained that attenuation of the amplitude of the receptor potential was caused by modification of membrane characteristics by extreme lowering of \([\text{Ca}^{2+}]_o\). When the plasma membrane was depolarized to about 0 mV by adding 100 mM KCl, responses in the negative direction were induced upon mechanical stimulation. When the plasma membrane was depolarized by adding 50 mM K_2SO_4, responses in the positive direction were induced. Thus, \( \text{Cl}^- \) channels may be involved in responses induced by mechanical stimulation under \( K^+ \)-induced depolarization.

Key words: Action potential — \( \text{Ca}^{2+} \) channel — \textit{Chara} — \( \text{Cl}^- \) channel — Mechano-perception — Receptor potential.

Some plants, such as \textit{Mimosa} and carnivorous plants, respond to mechanical stimuli with dynamic motile responses (Sibaoka 1991). What is now becoming evident is that non-motile plants also seem to perceive mechanical responses (Sibaoka 1991). What is now becoming evident is that non-motile plants also seem to perceive mechanical responses (Sibaoka 1991). On the other hand, channel inhibitors significantly inhibited mechanically induced action potential (Staves and Wayne 1993, Shimmen 1997). Although the receptor potential even at high concentrations (Shimmen 1997). The results showed that the electrogenic proton pump does not play an essential role in generating the receptor potential. It was also found that inhibitors of \( \text{Ca}^{2+} \) and \( \text{Cl}^- \) channels do not affect the receptor potential even at high concentrations (Shimmen 1997).

The generation of receptor potentials is a mechanosensitive process, and the subsequent action potential is a voltage-sensitive process. Therefore, to elucidate the first step of mechanoperception, the receptor potential must be analyzed. The ionic mechanism of the receptor potential for mechanoperception in plant cells was first challenged by Shimmen (1997). Shimmen (1996) developed a simple apparatus for electrophysiological analysis of the mechanoperception of characean cells. This apparatus was used to study the effects of inhibitors of the proton pump and ion channels (Shimmen 1997). The results showed that the electrogenic proton pump does not play an essential role in generating the receptor potential. It was also found that inhibitors of \( \text{Ca}^{2+} \) and \( \text{Cl}^- \) channels do not affect the receptor potential even at high concentrations (Shimmen 1997).

Some plants, such as \textit{Mimosa} and carnivorous plants, respond to mechanical stimuli with dynamic motile responses (Sibaoka 1991). What is now becoming evident is that non-motile plants also seem to perceive mechanical responses (Sibaoka 1991). On the other hand, channel inhibitors significantly inhibited mechanically induced action potential (Staves and Wayne 1993, Shimmen 1997). Although the receptor potential even at high concentrations (Shimmen 1997). The results showed that the electrogenic proton pump does not play an essential role in generating the receptor potential. It was also found that inhibitors of \( \text{Ca}^{2+} \) and \( \text{Cl}^- \) channels do not affect the receptor potential even at high concentrations (Shimmen 1997).

Some plants, such as \textit{Mimosa} and carnivorous plants, respond to mechanical stimuli with dynamic motile responses (Sibaoka 1991). What is now becoming evident is that non-motile plants also seem to perceive mechanical responses (Sibaoka 1991). On the other hand, channel inhibitors significantly inhibited mechanically induced action potential (Staves and Wayne 1993, Shimmen 1997). Although the receptor potential even at high concentrations (Shimmen 1997). The results showed that the electrogenic proton pump does not play an essential role in generating the receptor potential. It was also found that inhibitors of \( \text{Ca}^{2+} \) and \( \text{Cl}^- \) channels do not affect the receptor potential even at high concentrations (Shimmen 1997).

On the other hand, channel inhibitors significantly inhibited mechanically induced action potential (Staves and Wayne 1993, Shimmen 1997). Although the receptor potential was insensitive to the above channel inhibitors, Shimmen (1997) suggested that \( \text{Ca}^{2+} \) and or \( \text{Cl}^- \) channels are involved in generating receptor potentials, based on the equilibrium potential of these ions across the plasma membrane. However, this conclusion is still tentative. To find ion channels involved in generating receptor potentials, this study was done to analyze the effects of modifying \( \text{Ca}^{2+} \) and \( \text{Cl}^- \) concentrations in the external medium on the amplitude of the receptor potentials.
**Materials and Methods**

*Chara corallina* was cultured as reported by Mimura and Shimmen (1994). Internodal cells were isolated from neighboring cells and their lengths were adjusted to about 4 cm by ligation with polyester thread and cutting. Cells thus prepared were kept in artificial pond water (APW) containing 0.1 mM KCl, 0.1 mM CaCl₂ and 1 mM NaCl.

Mechanical stimulation and electrical measurement were carried out using the apparatus as reported previously (Fig. 1 in Shimmen (1996)). A cell was partitioned into two halves using a chamber composed of two pools. One pool (B) was filled with 100 mM KCl solution and other pool (A) with APW supplemented with 180 mM sorbitol, and the potential difference between the two pools was measured. The pH values of both APW supplemented with sorbitol and KCl solution were adjusted to 7.0 with 5 mM HEPES-Tris. Hereafter, the APW (pH 7.0) supplemented with 180 mM sorbitol is simply called APW. Under such conditions, the membrane potential (E_m) of the cell part bathed in pool A filled with APW can be measured without inserting a microelectrode (K-anesthesia method, Shimmen et al. 1976). The E_m was recorded using an amplifier (Nihon Kohden MEZ7101) and a pen-writing recorder (National, VP-6521A or VP-654A). Mechanical stimuli were applied to the cell part in pool A by dropping onto it a piece of glass tubing of 1.3 g. The intensity of the stimulus was controlled by changing the height (H) from which the tubing was dropped (Shimmen 1996). Stimuli were applied at about 30-s interval. When the cell generated an action potential, the subsequent stimulation was carried out after 7-10 min.

The effects of changing ion concentrations on mechanosensitivity were evaluated by comparing the amplitudes of receptor potentials generated by stimuli of same intensity. Since the intensity of the stimulus adopted to evaluate the sensitivity was different among the cells, statistical analysis was difficult. Therefore, the results are described qualitatively. Experiments were carried out at room temperature (22-26°C).

**Results**

*Effects of decrease in the Ca²⁺ concentration—* The equilibrium potential for Ca²⁺ across the plasma membrane (E_{Ca}) is significantly positive inside (Williamson and Ashley 1982) and the Ca²⁺ channel plays a central role in generating action potentials (Lunevsky et al. 1983, Shiina and Tazawa 1987a, Tsutsui et al. 1987, Tsutsui and Ohkawa 1993). Presence of mechanosensory Ca²⁺-selective cation channel and stretch-activated Ca²⁺ channel in plant membrane has been reported (Ding and Pickard 1993, Garril et al. 1992). To examine possible involvement of Ca²⁺ channel in receptor potential, the effect of lowering the Ca²⁺ concentration of the external medium ([Ca²⁺]_o) was examined. To decrease [Ca²⁺]_o, EGTA at 1 mM was added to APW and the pH was adjusted with Tris. To prepare a medium of pCa 3, 2 mM CaCl₂ was added to APW containing 1 mM EGTA. Media of pCa 6 and 7 were prepared using the association constant between EGTA and Ca²⁺, 4.83 × 10⁹ M⁻¹ (Jewell and Ruegg 1966). The resting membrane potential ([E_{m0}]) in APW of pCa 3 averaged −234 mV (Table 1). By decreasing [Ca²⁺]_o to pCa 6, (E_m) significantly changed in the negative direction (−240 mV). When [Ca²⁺]_o was further decreased to pCa 7, (E_m) was slightly changed in the positive direction (−203 mV). By decreasing [Ca²⁺]_o, the membrane potential at the peak of the action potential ([E_{pA}]) significantly changed in the negative direction, resulting in attenuation of the amplitude of the action potential (Table 1, Fig. 1). The effect of lowering [Ca²⁺]_o on the receptor potential was examined by comparing the amplitude of the receptor potential generated by stimuli of the same intensity. In Fig. 1, the amplitudes of receptor potentials generated by stimuli from H of 1 cm were compared. When [Ca²⁺]_o decreased to pCa 7, the amplitude of the receptor potential increased. However, this was not a general tendency. The effect of pCa 6 and 7 varied among the cells. By decreasing [Ca²⁺]_o, the amplitude of the receptor potentials increased in five cells, decreased in five cells, and did not change in three cells. Thus, the amplitude of the receptor potential does not seem to be affected by decreasing [Ca²⁺]_o to pCa 6 and 7.

To extremely reduce [Ca²⁺]_o, the medium was prepared by adding 1 mM EGTA to APW lacking CaCl₂ (APW(−CaCl₂)). When APW(−CaCl₂) supplemented with 1 mM EGTA was added to the external medium, (E_m) changed in the positive direction and action potentials were repetitively generated. Only in rare cases (3 cells), was the action potential not generated for some period. In the cell shown in Fig. 2, mechanical stimulation in the presence of 1 mM EGTA was possible. By adding EGTA, (E_m) significantly changed in the negative direction, resulting in attenuation of the amplitude of the action potential. The amplitude of the receptor potential generated by stimuli from H of 0.5 cm decreased when EGTA was added.
Table 1 Effect of [Ca$^{2+}$]o on the resting membrane potential ($E_m$) (mV) and the membrane potential at the peak of action potentials ($E_{Ja}$) (mV)

<table>
<thead>
<tr>
<th>pCa</th>
<th>$E_m$</th>
<th>$E_{Ja}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-234</td>
<td>-8</td>
</tr>
<tr>
<td>6</td>
<td>-240</td>
<td>-37</td>
</tr>
<tr>
<td>7</td>
<td>-203</td>
<td>-65</td>
</tr>
</tbody>
</table>

Average values of 13 cells are shown with standard errors.

Effect of increase in the Cl$^-$ concentration—The equilibrium potential for Cl$^-$ across the plasma membrane ($E_{Cl}$) is also positive inside (Tazawa et al. 1974) and the Cl$^-$ channel is involved in generating action potentials (Lunevsky et al. 1983, Shiina and Tazawa 1987b, 1988, Tsutsui et al. 1986). Presence of stretch-activated anion channel in plant membrane has been reported (Falke et al. 1988). To examine possible involvement of Cl$^-$ channel in generation of receptor potential, the effect of increasing [Cl$^-$]$o$ was examined. To increase [Cl$^-$]$o$, 50 mM choline chloride was added to APW, and the osmolarity was adjusted by decreasing the sorbitol concentration. By increasing [Cl$^-$]$o$, $E_{Ja}$ slightly changed in the positive direction. $E_{Ja}$ did not change (Table 2). The amplitude of the receptor potential generated by stimuli from $H$ of 2 cm was not affected by increasing [Cl$^-$]$o$. By increasing [Cl$^-$]$o$, the amplitude of the receptor potential did not change in six cells, increased in one cell and slightly decreased in one cell. Thus, the amplitude of the receptor potential does not seem to change when [Cl$^-$]$o$ is increased to 50 mM.

Effect of both decreasing [Ca$^{2+}$]o and increasing [Cl$^-$]o—To examine the effect of both decreasing [Ca$^{2+}$]$o$ and increasing [Cl$^-$]$o$, 1 mM EGTA and 50 mM choline chloride were added to APW (−CaCl$_2$). The osmolarity was adjusted by decreasing the sorbitol concentration. Upon addition of the medium, $E_m$ significantly changed in the positive direction (Fig. 4, Table 3). In this case, repetitive action potentials were not generated. It is suggested that decrease in the concentration of divalent cation (addition of EGTA) and increase in the concentration of monovalent cation (addition of choline) caused drastic changes in the membrane potential.
Table 2  Effects of 50 mM choline chloride on the resting membrane potential ((E_jr) (mV) and the membrane potential at the peak of action potentials ((E_ja) (mV))

<table>
<thead>
<tr>
<th>Cell No.</th>
<th>(E_jr)</th>
<th>(E_ja)</th>
<th>Average</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2</td>
<td>-7</td>
<td>-205</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3</td>
<td>-11</td>
<td>2</td>
</tr>
</tbody>
</table>

Average values of 8 cells are shown with standard errors.

Table 3  Response direction in relation to resting potential ((E_jr) (mV) in the presence of both 1 mM EGTA and 50 mM choline chloride

<table>
<thead>
<tr>
<th>Cell No.</th>
<th>(E_jr)</th>
<th>Direction of response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2</td>
<td>negative</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>negative</td>
</tr>
<tr>
<td>3</td>
<td>-45</td>
<td>positive</td>
</tr>
<tr>
<td>4</td>
<td>-35</td>
<td>positive</td>
</tr>
<tr>
<td>5</td>
<td>-35</td>
<td>positive</td>
</tr>
<tr>
<td>6</td>
<td>-40</td>
<td>positive</td>
</tr>
<tr>
<td>7</td>
<td>-35</td>
<td>positive</td>
</tr>
<tr>
<td>8</td>
<td>-30</td>
<td>positive</td>
</tr>
<tr>
<td>9</td>
<td>-45</td>
<td>positive</td>
</tr>
</tbody>
</table>

membrane depolarization (Shimmen et al. 1976).

Even under large depolarization, the cell showed responses upon mechanical stimulation. Two types of responses were observed: one in the negative direction (Fig. 4A) and the other in the positive direction (Fig. 4B). The direction of the response was dependent on (E_jr). When (E_jr) was more negative than -30 mV, the response was in the positive direction (Table 3, Cell No. 3-9). When (E_jr) was more positive, the response was in the negative direction (Table 3, Cell No. 1 and 2).

Response under K-induced depolarization—The above experiments (Fig. 4, Table 3) showed that the response in the negative direction was induced under large depolarization. However, it was difficult to control (E_jr) using the medium containing EGTA and choline chloride. The level of (E_jr) depended on the cells used (Table 3). Since (E_jr) is strongly dependent on the concentration of K⁺ in the external medium (Shimmen and Tazawa 1977), (E_jr) could be brought to about 0 mV by increasing the K⁺ concentration. KCl at 100 mM was added to APW lacking sorbitol. In some cells, (E_jr) changed to about 0 mV just after the addition of 100 mM KCl. In most cells, however, (E_jr) remained at levels more negative than -100 mV after addition of 100 mM KCl (Fig. 5). In the presence of 100 mM KCl, (E_jr) became unstable. By mechanical stimulation from H of 0.5 cm, a response in the positive direction was observed. Upon stimulation from H of 1 cm, the cell generated an action potential. Small repolarization, E_m again changed in the positive direction and remained at about 0 mV.

After 5 min of depolarization, the cells were stimulated at about 30-s intervals. As expected, responses in the negative direction were induced by mechanical stimulation.

Fig. 4  Response of E_m in the presence of EGTA and choline chloride. Cells were stimulated in APW(—CaCl₂) supplemented with 1 mM EGTA and 50 mM choline chloride. Numbers below the E_m trace show H (in cm) from which a piece of glass tubing was dropped. In cell A, responses in the negative direction were observed. In cell B, responses in the positive direction were observed.

Fig. 5  Depolarization in the presence of 100 mM KCl. E_m was first measured in APW. At the time shown by the arrowhead, 100 mM KCl was added. (E_m) became unstable. When the cell was stimulated from H of 0.5 cm, an receptor potential was generated. The stimulus from H of 1 cm caused an action potential. After a brief repolarization, the membrane again depolarized and remained at the depolarized level. Numbers below the E_m trace show H (in cm) from which a piece of glass tubing was dropped.
Fig. 6 Responses in APW supplemented with 100 mM KCl. Upon stimulation, a cusp in the positive direction and a subsequent response in the negative direction were induced. Stimuli from H of 1, 2 and 3 cm induced a small cusp. However, no cusp was observed upon stimulation from H of 4 and 5 cm. Numbers below the E_m trace show H (in cm) from which a piece of glass tubing was dropped. A cusp generated by the stimulus from H of 3 cm is shown by an arrowhead.

The amplitude of the response was dependent on the intensity of the stimuli (Fig. 6). In most cases, however, the amplitude of the responses decreased when the stimuli were repeated, presumably due to damage by stimulation under unusual ionic conditions. In the present study, the direction and not the amplitude of the response was analyzed, as the amplitude varied. In addition, the amplitude of the responses decreased with time, even when cells were kept without stimulation. Therefore, experiments were always carried out within 20 min after addition of K+ of high concentrations.

Before a large response in the negative direction, a small and rapid response in the positive direction was observed (Fig. 6 arrowhead). This small response, observed in many cases, hereafter, referred to as the "cusp". In the present study, the slow and large response was analyzed but not the cusp. The direction of the response was dependent on [Cl\textsuperscript{-}]_o (Fig. 7). First, responses in the negative direction were observed in APW supplemented with 100 mM KCl. Next, the external medium was changed to APW supplemented with 50 mM K\textsubscript{2}SO\textsubscript{4} and 65 mM sorbitol to decrease [Cl\textsuperscript{-}]_o to 1.3 mM. The cell was stimulated after 5 min of exchange of the medium. In this case, the direction of the responses was positive. No cusp was observed, presumably due to masking by a large response in the positive direction. When the external medium was again changed to

![Fig. 7 Change of direction of responses by exchange of KCl with K\textsubscript{2}SO\textsubscript{4}. The cell was stimulated in APW supplemented with 100 mM KCl, APW supplemented with 50 mM K\textsubscript{2}SO\textsubscript{4} and then APW supplemented with 100 mM KCl. In APW supplemented with 100 mM KCl, a cusp and a subsequent response in the negative direction were induced. In APW supplemented with 50 mM K\textsubscript{2}SO\textsubscript{4}, a response in the positive direction was induced. Numbers below the E_m trace show H (in cm) from which a piece of glass tubing was dropped.](https://academic.oup.com/pcp/article-abstract/38/6/691/1868760/fig?js=1&fig=fig7)

Table 4 Effect of [Cl\textsuperscript{-}]_o on response-direction

<table>
<thead>
<tr>
<th>Cell No.</th>
<th>(KCl)_o (mM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>–</td>
</tr>
<tr>
<td>4</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>–</td>
</tr>
<tr>
<td>6</td>
<td>–</td>
</tr>
<tr>
<td>7</td>
<td>–</td>
</tr>
<tr>
<td>8</td>
<td>–</td>
</tr>
<tr>
<td>9</td>
<td>–</td>
</tr>
<tr>
<td>10</td>
<td>–</td>
</tr>
<tr>
<td>11</td>
<td>–</td>
</tr>
</tbody>
</table>

+: response in positive direction, -: response in negative direction, ND: not determined, ?: direction of response could not be judged. [K\textsuperscript{+}]_o was adjusted at 100 mM by adding K\textsubscript{2}SO\textsubscript{4}.
100 mM KCl, a cusp and a subsequent response in the negative direction were observed. \((E_a)\), in the presence of 100 mM KCl was \(-0.3\pm0.5\) mV \((n=33)\) and that in the presence of 50 mM K2SO4 was \(-4.5\pm1.5\) mV \((n=19)\).

The dependence of the direction of responses on \([\text{Cl}^-]_o\) was further analyzed. The KCl concentrations were changed in the order of 100, 50 and 30 mM (Fig. 8). K+ concentration and osmolarity were adjusted with K2SO4 and sorbitol, respectively. In the presence of 100 mM KCl, a cusp and a subsequent slow response in the negative direction were observed. By decreasing \([\text{Cl}^-]_o\) to 50 mM, the amplitude of the cusp slightly increased and that of the slow response in the negative direction significantly decreased. By decreasing \([\text{Cl}^-]_o\) to 30 mM, the amplitude of the response in the negative direction became very small.

The dependence of the direction of the slow response on \([\text{Cl}^-]_o\) is summarized in Table 4. At 100 mM \([\text{Cl}^-]_o\), all cells showed responses in the negative direction. At 50 mM \([\text{Cl}^-]_o\), five cells showed responses in the negative direction and three cells in the positive direction. In one cell, the direction of the response could not be judged. At 30 mM \([\text{Cl}^-]_o\), the responses in the positive direction were observed in most cells. In one cell, small response in the negative direction was observed (Cell No. 11).

**Discussion**

This is the first report analyzing the effects of external Ca2+ and Cl− on receptor potentials induced by mechanical stimulation in plant cells. Although Characeae has no sensory cells, it is very suitable for analyzing the receptor potential because of its advantages as a tool for electrophysiological study (Shimmen et al. 1994).

When \([\text{Ca}^{2+}]_o\) was lowered to pCa 6 or 7, the amplitude of the receptor potential was not affected. This result is reasonable, considering the equilibrium potential for Ca2+ across the plasma membrane \((E_{Ca})\), which is calculated with the following equation:

\[
E_{Ca} = 29 \log \frac{[\text{Ca}^{2+}]_o}{[\text{Ca}^{2+}]_c}
\]

where \([\text{Ca}^{2+}]_o\) and \([\text{Ca}^{2+}]_c\) represent \([\text{Ca}^{2+}]\) in the external medium and that in the cytoplasm, respectively. Williamson and Ashley (1982) reported that \([\text{Ca}^{2+}]_o\) at the resting state is 0.22 µM in Chara. Using this value, \(E_{Ca}\) is calculated to be 106, 19 and -9.9 mV at pCa 3, 6 and 7, respectively. \((E_m)\), at pCa 3, 6 and 7 was -234, -240 and -203 mV, respectively (Table 1). Thus, \((E_m)\) is significantly more negative than \(E_{Ca}\) at all \([\text{Ca}^{2+}]_o\). When 1 mM EGTA is added to APW from which CaCl2 has been removed, \(E_{Ca}\) should significantly change in the negative direction. Under such conditions, the amplitude of the receptor potential is decreased (Fig. 2). From this result, it is tentatively concluded that the Ca2+ channel might be involved in generating the receptor potential. However, the possibility remains that attenuation of the amplitude of the receptor potential was caused by modification of membrane characteristics by extreme lowering of \([\text{Ca}^{2+}]_o\) but not by change of \(E_{Ca}\).

To examine the possible involvement of Cl− channels, \([\text{Cl}^-]_o\) was increased to 50 mM (Fig. 3, Table 2). \(E_{Cl}\) was calculated with the following equation:

\[
E_{Cl} = 58 \log \frac{[\text{Cl}^-]_c}{[\text{Cl}^-]_o}
\]

where \([\text{Cl}^-]_c\) and \([\text{Cl}^-]_o\) represent \([\text{Cl}^-]\) in the cytoplasm and that in the external medium, respectively. Tazawa et al. (1974) reported \([\text{Cl}^-]\), to be 21 mM in Chara. Using this value, \(E_{Cl}\) for cells bathed in APW supplemented with 50 mM choline chloride is calculated to be -22 mV, which is significantly less negative than \((E_m)\) (-205 mV). Even when 100 mM choline chloride was added, \(E_{Cl}\) was calculated to be -39 mV. Further increase in the concentration of choline chloride is not technically possible. Thus, it is difficult to make \(E_{Cl}\) more negative than \((E_m)\), by adding choline chloride.

To carry out analysis based on equilibrium potential for ions in cells bathed in physiological medium, voltage clamping experiments are recommended. However, in the K-anesthesia method, a large electrical resistance between two pools (series resistance) cannot be avoided (Shimmen et al. 1976). Therefore, it is difficult to clamp the membrane potential at the desired level. To carry out a voltage clamping experiments, a measuring apparatus without a large series resistance must be developed. In the present study, however, analysis of Cl− channel based on the equilibrium potential became possible by depolarizing the membrane with 100 mM K+ (Fig. 7, Table 4).

In the presence of 100 mM KCl, the response was in the positive direction before the depolarization (Fig. 5) and was in the negative direction after depolarization (Fig. 6). The response in the negative direction was also induced in the absence of K+ at high concentration, when the membrane was significantly depolarized (Table 3 Cell No. 1 and 2). Thus, it is concluded that the response in the negative direction was induced by depolarization but not by an increase in K+ concentration.

K+ concentration in the cytoplasm has been reported to be 112 mM (Tazawa et al. 1974). In the presence of 100 mM K+ in the external medium, the equilibrium potential for K+ across the plasma membrane is calculated to be 2.8 mV. Thus, \((E_m)\) in the presence of 100 mM KCl \((-0.3\) mV) is close to \(E_K\). \(E_{Cl}\) in the presence of 100 mM KCl in the external medium is calculated to be -39 mV, which is more negative than \((E_m)\). Reflecting the situation, \((E_m)\) changed in the negative direction upon mechanical stimulation in the presence of 100 mM KCl (Fig. 6, 7). When the external medium was changed to APW supplemented with 50 mM K2SO4, \([\text{Cl}^-]_o\) was 1.3 mM and \(E_{Cl}\) was calculated.
Mechano-perception in Characeae

References


