The pyramidal cell at hippocampus is highly full of variety in its shape and size. In the growth process, each cell has changed the shape to adapt to the region and function in the hippocampus. However it has still been unclear how to adapt functionally. The previous researches (Mainen and Sejnowski, 1996; Winslow et al., 1999; Duijnhouwer et al., 2001; Krichmar et al., 2002) focused on dendritic morphology and the variation in the dendritic resistance. The authors assume that somatic configuration has also an influence on information processing dynamics in neuron. The processing dynamics can be influenced by neuron shape through spreading speed of membrane potential and property of membrane integration. Because of strong nonlinearity of the membrane dynamics, they are complicatedly tangled and they modulate and modify the function of neuronal circuit. The authors (Hirose and Murakami, 2002) previously predicted that the signal velocity v on a round soma has a dependence of $v \propto D^{0.77}$ on the conductive-layer thickness D by using a two-dimensional membrane-potential model. We also (Sakatani and Hirose, submitted) reported preliminarily the influence of variation of the somatic resistance on the firing characteristics. We predicted that the shape of the apical-dendrite hillock have an influence on the firing rate and firing latency. In this paper, we evaluate quantitatively the influence of the difference in the sharpness and the symmetry on the firing rate in detail.

We construct a new neuronal model of the pyramidal cell at the CA3 hippocampus by proposing micro-compartmental models to analyze the firing rate quantitatively. We present micro-compartmental soma models where we choose the total surface areas unchanged when the curvatures are varied. We construct $Model A$, B and C from asymmetry to symmetry. Each model has three cells which is different in the sharpness. We construct Model A_1, A_2 and A_3 from the blunter to the sharper. We also construct $Model B_{1,2,3}$ and $C_{1,2,3}$ in the same way.

We calculate the firing frequency when the center of the soma is stimulated. The CA3 cells express three different modes of firing in response to steady injection of current into the soma, depending on the magnitude of the injected current (Wong and Prince, 1981). The soma generates rhythmic bursts at low frequency for small injected current 0–0.3 nA (Hablitz and Johnston, 1981). At somewhat higher currents 0.3–0.4 nA, rhythmic bursts with intercalated runs of fast spikes occur. At sufficiently large current more than 0.4 nA, rhythmic couple action potentials are observed after an initial burst and rhythmic single action potentials are observed after hundreds of milliseconds. The action potential rate is calculated during 1000 ms from first firing time after an initial burst.

We calculated the firing rate versus somatic current injection for three degree of sharpness to analyze the effect of the somatic symmetry to the firing rate. In the bursting mode, the firing rates are the same among the cells which have the difference in symmetry. However, there is the difference in the turning current where the firing mode is changed from bursting mode to bursting with intercalated runs of first spikes. The turning current in model C_1 is less than those in model A_1 and B_1. The turning current among model A_2, B_2 and C_2 are almost the same. The turning current in model C_3 is also less than those in model A_3 and B_3. The turning current tends to be larger as the sharpness of the cell is sharper. In the repetitive action potential mode, the firing rates vary among the cells which have the difference in symmetry. The firing rate in Model B_1 is larger than those in Model A_1 and C_1. The firing rate in Model A_2 is also larger than those in Model B_2 and C_2. The firing rate tends to be higher as the turning current from bursting with intercalated runs of first spikes to repetitive action potential mode is smaller. The turning time from couple spiking mode to single one are different among $Model\ A_{1,2,3}$, among $B_{1,2,3}$ and among $C_{1,2,3}$. The difference among firing rate is caused by the turning time difference.

We calculated the firing rate versus somatic current injection for three degree of symmetry to analyze the effect of the somatic sharpness to the firing rate. In the bursting mode, the firing rates are the same among the cells which have the difference in sharpness. However, there is the difference in the turning current where the firing mode is changed from bursting mode to bursting with intercalated runs of first spikes. The turning currents in the shaper cells are larger than those of others. In the repetitive action potential mode, the rate difference exists among only symmetrical cells. The firing rate in Model C_1 is larger than those in Model C_2 and C_3. In $Model\ C_1$, the turning time from couple spiking mode to single one is earlier than those in Model C_2 and C_3. On condition that the symmetrical degree is the same, the difference among firing rate is also caused by the turning time difference.

In this paper, micro-compartmental model method is proposed as a low calculation cost and significantly effective technique to estimate the spatiotemporal membrane potential dynamics. We evaluate quantitatively the influence of the variation in the symmetry and the sharpness on the firing rate in detail. We construct neuronal micro-compartmental models of the pyramidal cell at the CA3 hippocampus to analyze the shape dependence on the firing rate. Calculations reveal the following facts. Bursting frequencies (lower frequency) are the same for difference in the symmetry and sharpness, However the differences of repetitive action potential frequency (higher frequency) are exists. The frequency differences depend on turning time from couple spiking mode to single one.