# **Appendix 1: Review of the previous standard vertex model**

# For reference, we review the formulation of a standard vertex model [2]. The potential function of the previous standard vertex model is given by

|  |  |  |
| --- | --- | --- |
|  | , | (A.1) |

# which gives the mechanical forces generated by cells with the derivative of . The definitions and meanings of , , , are the same as those given in Eq. (1) in the main text. The quantity is a constant that represents the resultant strength of the line tension at cell boundary , where both contraction and adhesion on cell boundary are considered. and are positive constants. is the perimeter of the *α*th cell, given by . The third term in Eq. (A.1) is sometimes expressed by the term [9]. However, the two terms and are essentially the same because we can rewrite the former term to the latter by including the effects of the existence of in the second term in . The time evolution equation for position of the ith vertex is given by

|  |  |  |
| --- | --- | --- |
|  | , | (A.2) |

where  is a friction coefficient. We can solve Eq. (A.2) for  under appropriate initial conditions for  and boundary conditions of the cell sheet.

# **Appendix 2: Equivalence between an increase in in the present vertex model and a decrease in the line tension in the previous vertex model**

# In this appendix, we consider the equilibrium shape of a cell as described by the previous and present vertex models and show the equivalence between an increase in of a cell boundary in the present vertex model and a decrease in the line tension on the cell boundary in the previous vertex model. Let us consider a cell that is represented by an *n*-sided convex polygon. The length of the *i*th segment of the cell is denoted by . In the previous vertex model described in Appendix 1, the potential function of the cell is given by

# ,

# where is a constant that contains the effects of both contraction and adhesion on cell boundary . is the area of the cell, and and are positive constants. The equilibrium conditions for this cell shape are given by , that is,

|  |  |  |
| --- | --- | --- |
|  |  | (B.1) |

# for *i* = 1, 2, …, *n*. Next, we consider the equilibrium conditions for the cell shape in the present vertex model described in Eqs. (1)–(4) in the main text. The potential function of the cell is given by

# ,

# where is a constant that represents the strength of contraction force on cell boundary . The time evolution equations for are given by

# for *i* = 1, 2, …, *n*,

# where , and is the relaxation time assigned to the *i*th cell boundary. The equilibrium conditions for this cell shape with this model are given by and , and hence

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | | | (B.2） |
|  | | . | (B.3） | |

# By solving Eq. (B.2) for , we have

|  |  |  |
| --- | --- | --- |
|  | . | (B.4） |

# Substituting Eq. (B.4) into Eq. (B.3) and rearranging the equation yield

|  |  |  |
| --- | --- | --- |
|  | , | (B.5) |

# where we have set . Splitting into a constant and its deviation as , and introducing new quantities and

|  |  |  |
| --- | --- | --- |
|  | , | (B.6) |

# we obtain

|  |  |  |
| --- | --- | --- |
|  | , | (B.7) |

# for *i* = 1, 2, …, *n*. Eq. (B.7) has the same form as that of Eq. (B.1), that is, the equilibrium shape of the cell described in the present vertex model is determined by equations having the same form as that of the previous vertex model. While and in Eq. (B.7) contain all the variables {} that must be determined, the quantity appearing in and does not depend on the free index . Hence, we can regard Eq. (B.7) as self-consistent equations for {}, and regard in Eq. (B.7), which is given in Eq. (B.6), as a resultant line tension in the present vertex model in the equilibrium state when ’s are finite. If , which usually holds because of a large value of (from the situation where the amount of cell membrane is in excess relative to the cell perimeter), the resultant line tension on the cell boundary decreases when the cell boundary has a longer (). On the other hand, if of the cell boundary is shorter () than for other cell boundaries, the resultant line tension on the cell boundary increases. In this way, affects the resultant line tension at the cell boundary.