Supporting Information

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SI Text

Cell-Based Simulation of Pigment Pattern Formation: General Features of the Simulation. Behaviors of 2 types of cells (melanophores and xanthophores) are calculated in this simulator. Each cell releases 1 or 2 kinds of substances that diffuse in the field, and the behaviors (development, migration, and death) of the cells are determined by the stochastic functions of the concentration of the substances that exist in the cells. Calculations start at the condition that the melanophores and the xanthophores are scattered randomly, and then the iterations were continued until the patterns became stable.

Field. The size of the field was 100 columns × 100 columns.

Melanophore. A melanophore occupies a single column (1 × 1) in the field, releases a substance "Ms," and can migrate to the neighboring column. Probability of generation and death of melanophores is determined by the stochastic functions of the variables *Ms*, *Xs*, and *Xl*.

Xanthophore. A xanthophore occupies a single column (1 × 1) in the field, releases 2 substances "Xs" and "Xl," and can migrate to the neighboring column. Probability of the production and death of melanophores is determined by the stochastic functions of the variables *Ms*, *Xs*, and *Xl*.

Substances. ***Ms.*** Ms is produced by melanophores and diffuses in the field at low diffusion constant. Ms restricts the production and survival of xanthophores and mildly restricts the production of melanophores.
Xs. Xs is produced by xanthophores and diffuses in the field at low diffusion constant. Xs restricts the production and survival of melanophores and mildly restricts the production of xanthophores.
Xl. Xl is produced by xanthophores and diffuses in the field at high diffusion constant. Melanophores need Xl for their survival and development.

Calculation of the substances is as follows,

$$Ms(i,j,t+1) - Ms(i,j,t) = Cmsp^{*}Mel(i,j,t) - Cmsd^{*}Ms(i,j,t) + Dms^{*}(Ms(i+1,j,t) + Ms(i-1,j,t) + Ms(i,j+1,t) + Ms(i,j-1,t) - 4^{*}Ms(i,j,t))$$

$$Mel(i,j,t) = \begin{cases} 1 : melanophore \quad occupies \quad at \quad (i,j) \\ 0 : else \end{cases}$$

$$Xs(i,j,t+1) - Xs(i,j,t) = Cxsp^{*}Xan(i,j,t) - Cxsd^{*}Xs(i,j,t) + Dxs^{*}(Xs(i+1,j,t) + Xs(i-1,j,t) + Xs(i,j+1,t) + Xs(i,j-1,t) - 4^{*}Xs(i,j,t))$$

$$Xl(i,j,t+1) - Xl(i,j,t) = Cxlp^{*}Xan(i,j,t) - Cxld^{*}Xl(i,j,t) + Dxl^{*}(Xl(i+1,j,t) + Xl(i-1,j,t) + Xl(i,j+1,t) + Xl(i,j-1,t) - 4^{*}Xl(i,j,t))$$

$$Xan(i,j,t) = \begin{cases} 1 : Xanthophore \quad occupies \quad at \quad (i,\ j) \\ 0 : else \end{cases}$$

i, position in x axis; j, position in y axis; t, iteration number; *Cmsp*, production rate of Ms; *Cmsd*, decay rate of Ms; *Dms*, Ddiffusion rate of Ms; *Cxsp*, production rate of Xs; *Cxsd*, decay rate of Xs; *Dxs*, diffusion rate of Xs; *Cxlp*, production rate of Xl; *Cxld*, decay rate of Xl; *Dxl*, diffusion rate of Xl.

Behaviors of the Cells. Effects of the short range substances (Ms and Xs) are calculated as follows:

$$Mshort(i,j,t) = C1^{*}Ms(i,j,t) + C2^{*}Xs(i,j,t)$$

In the case of the xanthophore,

$$Xshort(i,j,t) = C3^{*}Ms(i,j,t) + C4^{*}Xs(i,j,t)$$

Cell death of new cells is calculated at every 100 iterations.

If the column where a melanophore exists satisfies at least 1 of following conditions,

$$Cmdths < Mshort(i,j,t),$$

$$Cmdthl > Xl(i,j,t),$$

then a melanophore in the position disappears at the probability of *Pmdth*.

If the column where a xanthophore exists satisfies the following condition,

$$Cxdths < Xshort(i,j,t)$$

then a new xanthophore appears at the probability of *Pxdth*.

Cell Appearance. Cell's appearance is calculated at every 100 iterations.

If a column is not occupied and satisfies the following conditions,

$$Cmapps > Mshort(i,j,t)$$

$$Cmappl < Xl(i,j,t)$$

then a melanophore appears at the probability of *Pmapp*.

If a column is not occupied and satisfies the following condition,

$$Cxdths > Xshort(i,j,t)$$

then a xanthophore appears at the probability of *Pxapp*.

Migration. Cell migration is calculated at every 100 iterations. If one of the neighboring columns has a smaller *Mshort* value or *Xshort* value, cells move there at the probability of 0.5.

Initial Condition. As the initial condition, 300 of both types of cell were dispersed randomly in the 200 × 200 field.

Simulation Results. In the calculation, parameters are determined as they satisfy the necessary conditions of Turing pattern formation (see text). By changing a parameter value *Cmdthl*, which determines the requirement of long-range factor (Xl) by melanophores to survive, the emerging pattern changes from yellow spots, stripes, and black spots. The pattern emerges around the iteration number 8,000, and the patterns ware stable at least until 30,000.

Parameter values for simulation 1 are as follows: *Cmsp* = 2,

$Cmsd = 0.2$, $Dms = 0.015$, $Cxs = 2$, $Cxsd = 0.2$, $Dxs = 0.015$, $Cxlp2.8$, $Cxld = 0.2$, $Dxl = 0.3$, $C1 = 1.5$, $C2 = 15$, $C3 = 11$, $C4 = 1.5$, $Cmdths = 3$, $Cxdths = 2.2$, $Cmdthl = 3.0$, $Cmapps = 1$, $Cxapps = 1$, $Cmappl = 0.6$, $Pmapp = 0.005$, $Pxapp = 0.2$, $Pmdth = 0.8$, and $Pxdth = 0.8$.

Parameter values for simulation 2 are as follows: $t = 30{,}000$, $Cmdthl = 5$, $t = 30{,}000$, $Cmdthl = 3.2$, $t = 30{,}000$, $Cmdthl = 2$. Other parameters are identical to those in simulation 1.

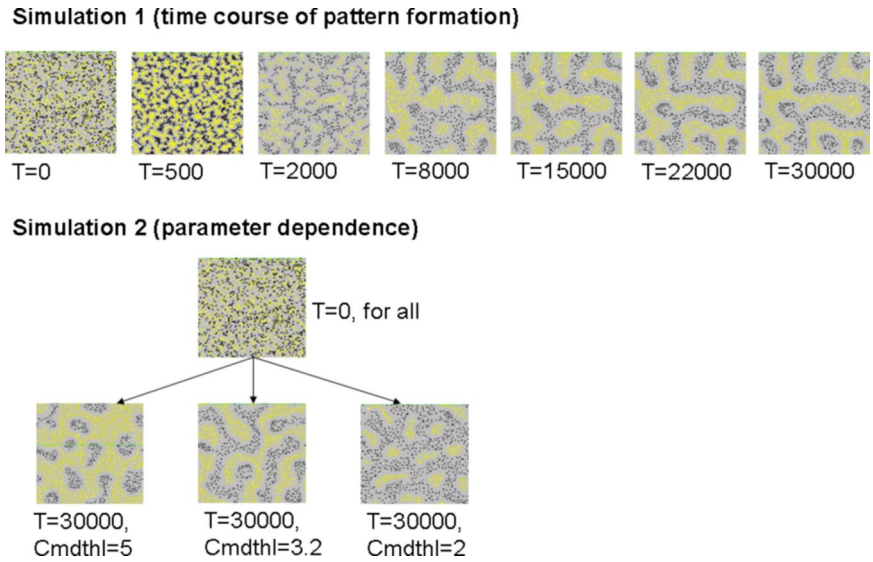

Fig. S1. (*Upper*) Cell-based simulation generating a stripe (no directionality) pattern. The simulation started from the random dispersion of melanophores and xanthophores. Generated patterns at the represented (T) iteration numbers were shown. (*Lower*) Generation of various 2D patterns from an identical random pattern. For these simulations, one of the parameter Cmdthl that specifies the sensitivity of melanophores to the long-range factor were changed.