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An information processing and body formation mechanism with its condition in development

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Abstract.

Conditions and a mathematical mechanism for a body to be able to form according to the information of genes in development without morphogen is considered and proposed. In other words the conditions and the method give the method to realize the body using the compressed informations. using the memories of genes. One of the purposes of this study is to make a mathematical model on PC for the formation simulation. The other is to find the way how for a real biological body to be formed.

1. Introduction.

Conditions and a mathematical mechanism for a body to be able to form according to the information of genes in development without morphogen is considered and proposed. In other words the conditions and the method give the method to realize the body using the compressed informations. using the memories of genes. One of the purposes of this study is to make a mathematical model on PC for the formation simulation. The other is to find the way how for a real biological body to be formed. Homeotic selector genes are known to be used to make the body in development (Ref. 4)..

The conditions for the body formation is that every pair of adjacent two cells should have a similar expressivity of each gene of all expressed genes in each cell keeping slope continuity. These are shown in section 3.

Cells with these conditions can have the following abilities.

(1) If there is an expressed gene in each cell by which the cell expresses the value of a point of a sine curve with a wave length, a big group of these cells can make the sine curve along the body length which means the group has a stability when they form the sine curve shape. The multiple sine curve formations with different wave lengths and different phases can be formed by having the different number of points in each cycle of each sine curve. This is shown in section 4.

(2) If three genes each of which gives an orthogonal sine curve are given, the condition with the assumption of the orthogonal character of genes like sine curves in a body shape formation can have ability to make a body segmentation like what is done by gap gene, pair-rule gene and segment-polarity gene (Ref. 4).

The character of the mechanism shown here seems to be able to have ability to reproduce a lost part of an organ like a tail with any shape from the top of the left part using multiple sine and cosine curves with different phases. This is also shown in section 6. All the mechanism shown here is based on the assumed character of orthogonalization of genes which is the main role played prevalently in the information processing in the brain.

2. The background to show why a set of curves like sine curves are used.

It is known that the activation mechanism of genes is very similar to that of neural networks (Ref. 4), moreover genes and neural networks have the mechanisms of mutation and synapse plasticity respectively which change their memories. So it is thought that these two systems are in closely

related situation basically.

In the formation of knowledge structure of neural networks, the basic character of memory compression works. Then in a hierarchical neural network, the formation of transformations, the production of general objects and concrete objects from lower layers to higher layers can be done (Ref. 1). A set of sine curves can have the characters of the transformations like location transformation . where the same objects with different locations are recognized as the same objects, and scale transformation, where the same objects with different scales are recognized as the same objects (Ref. 2). By these transformations, upper objects can be expressed by fewer informations effectively. If a sine curve expresses some information concerned with many objects, it can be said that the curve contribute much to the memory compression. Orthogonalization in the existence of multiple ceuves like sine curves also contribute to the memory compression.

In the case of genes, peptides or proteins are expressed effectively by genes making a hierarchical structure like polypeptide chains, the pair of α helix and β sheet and β-α-β motif (Ref. 4). Thinking from these memory structures, the existence of the character of the memory compression in the expression by genes can be inferred (Ref. 3).

From this background, a mechanism where a partial system of a body like an organ is expressed by a set of curves is shown.

3. About the conditions and the mechanism for genes to express a partial system of body using curves like sine curves and to be able to do computer simulation

When genes express a partial system of body using curves like sine curves, what kinds of conditions each gene or each set of cells must have is shown here.

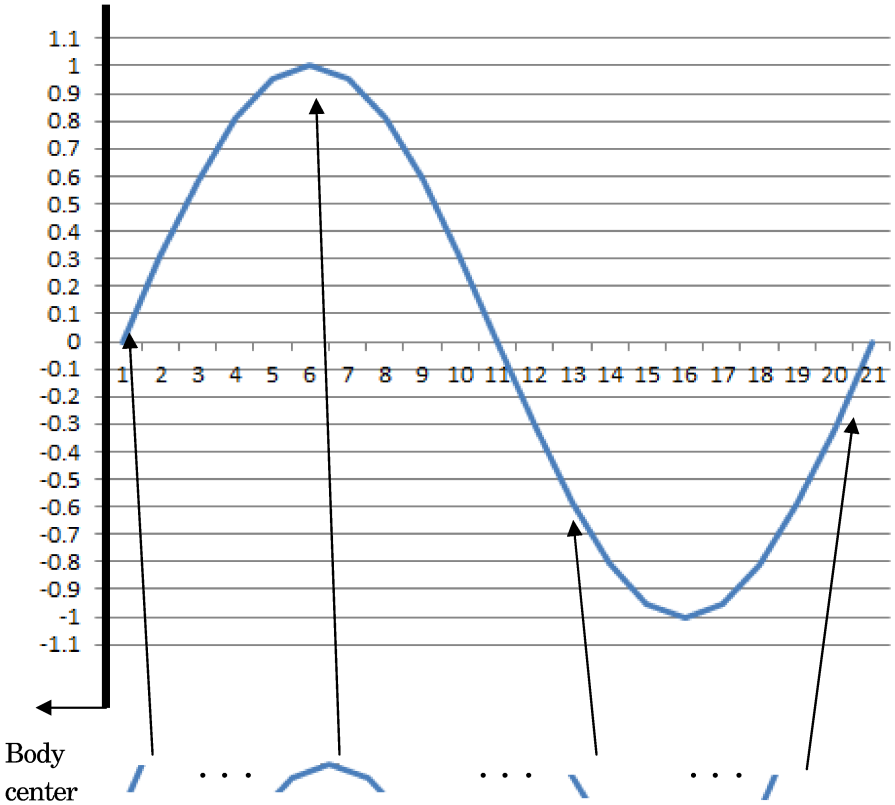

Fig. 1 A shape or a character distribution of a partial system of a body is expressed by a set of genes making the the partial system connecting the parts and their cells with the conditions shown in this section. At the bottom of the graph some of the parts of the curve are shown.

The meanings of Fig. 1 are shown as follows.

(1) It is assumed that a gene or a set of genes make the parts of a partial system of the body along the longer axis or the shorter axis of the system. Each part consists of cells with similar expressed characters and conditions shown below. The longer part consists of more cells.

(2) So as to meet the following conditions and align the parts with similar values keeping slope continuity, the set of genes put the next part at the top of the last part making the system grow.

(3) When the system is made according to the following conditions, the system is thought to have the biggest affinity and the **stability** which makes the connection among the cells of the system strong. Because all the parts and the cells of the parts can be joined making the total affinity the highest.

[conditions to connect cells]

(1) The most similar two parts where the expressed character value of the cells of one part is nearest to that of the other part are put adjacently.

(2) The character values must have slope continuity.

This means that when three parts are connected and the character values are

A, B and C where A>B>C, the order A-B-C must be kept. A-B-A makes distortion.

[The explanation of condition (2)]

If there are three sorts of cells A, B and C with a similar expressivity of a gene where A has the highest, C has the lowest and B has the average, then the parts are aligned in the order of A, B and C not being aligned like in A, B and A because the expressivity of B can not be nearly the average of those of the adjacent two A cells. and this makes a little distortion. This means holding of slope continuity.

4. Formation of a partial system of the body

Under the conditions and the mechanism shown in section 3, curves like sine curve can be expressed by a gene or a set of genes.

The case where two sine curves are expressed by two genes or two set of genes is shown in Fig. 2.1 The two sine curves make the curve shown in Fig. 2.2. So genes can express any curve by the conditions and the mechanism using multiple curves (and multiple set of genes) making the affinity between adjacent two parts more and more strong and specific.

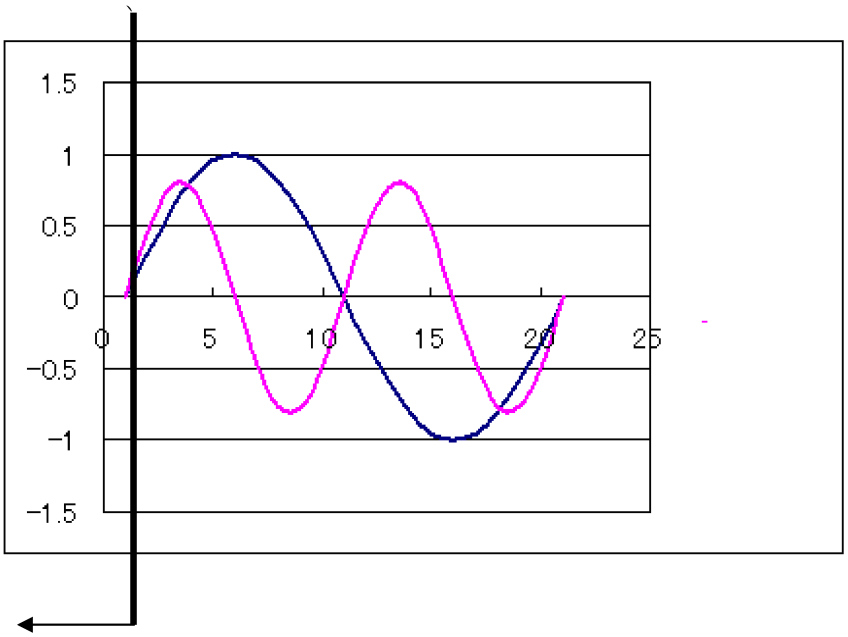

Fig. 2.1 Case with two characters and two sets of genes for them

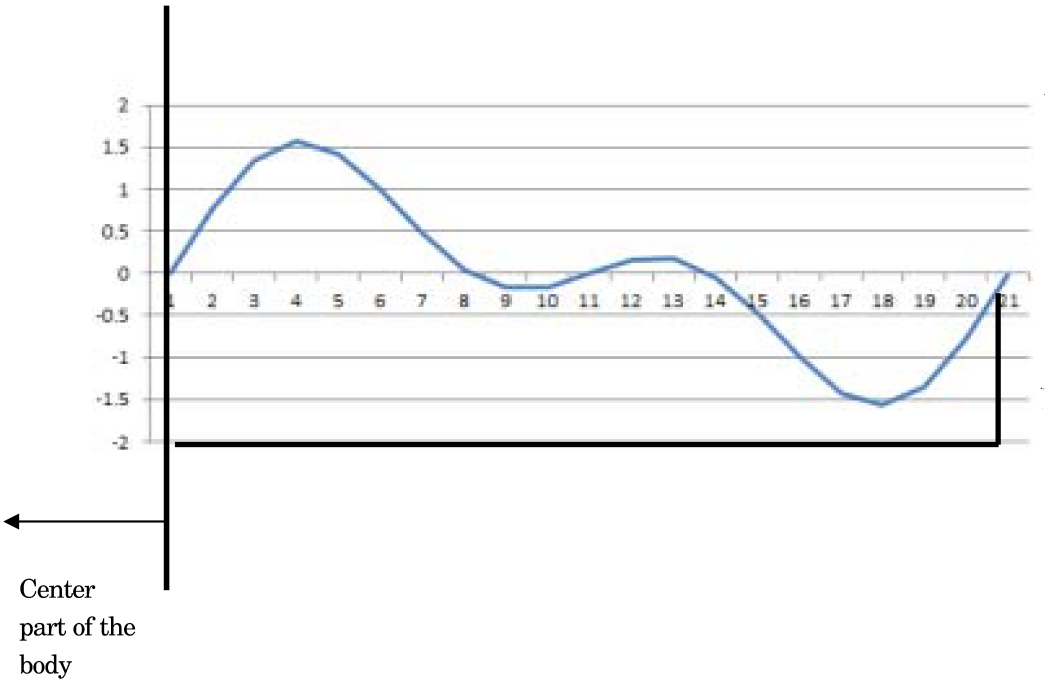

Fig. 2.2 The shape obtained from the two curves in Fig 2.1 by algebraic sum

The curve of Fig. 2.2 can express the distribution of any value.
So if the genes have the conditions and the mechanism, genes can not only express any curve but also have the possibility to express the whole body.

The examples which the genes can express are shown.

[Examples of the meanings which the curve in Fig. 2.2 can have.]
(1) Width distribution along the longer axis of a partial system of the body like a tail
(2) The distribution of some material in an interstitial tissue
(3) The distribution of secretion ability of an enzyme

5. The effect of the addition of competition and the necessity of the slope continuity in the conditions

The phenomena caused by positional value are shown in Fig 3. (Ref. 4) and can be partially explained by the conditions and the mechanism in section 3, and by the addition of competition condition can be explained.

The upper case 1 of Fig. 3 can be explained directly through the conditions and the mechanism. But the lower case 2 of of Fig. 3 can not be explained directly, but by adding competition to the conditions the lower case 2 of of Fig. 3 can be explained.

The competition is seen often in the dynamics of neural networks especially. The meaning of the competition is that as the result of competition to connect another part to the terminal being built next seeking the part and its cells with the biggest affinity, the part is chosen.

In the lower case 2 of of Fig. 3 the upper part of the leg has sub-parts 1, 2, 3, 4, 5, 6 lined in this order, and the lower part has sub-parts 4. 5. 6. 7, 8, 9, 10 lined in this order. Sub-part 7 of the upper part of the leg is connected to sub-part 4 of the lower part of the leg. So the situation of the upper part seeks 8 of the own parts for the elongation, but this elongation contradicts to the sub-part 4 of the lower part causing the competition. So by adding the condition of competition to the conditions shown in section 3, this case can be also explained. But it is imagined that in usual many cases the conditions shown in section 3 will be enough.

Even if the condition of competition is added, the condition of slope continuity can not be removed. Because cyclic patterns are seen often in the body as being able to be expressed by sine curves, then the repeated same parts can be connected mutually and directly without slope continuity.

6. Summary of what the conditions and the mechanism mean

What the conditions and the mechanism mean are summarized as follows.

(1) The conditions and the mechanism can express not only any shape of any partial system of the body, but also express any distribution of any quality in the system.
(2) By the conditions and the mechanism, genes can have the possibility to express not only the partial system but also the whole body by fewer ones causing memory compression. When like a sine curve some expression gives an information which is shared by many cells, it contributes much to the memory compression.
(3) If the informations memorized by genes are made orthogonal and produced through an efficient memory compression, the conditions and the mechanism give a method to realize into the body from the informations.
(4) Even if the tail of a body is cut off, through the conditions and the mechanism, the tail can be reproduced from the remained terminal thinking the conditions and the mechanism logically.
(5) By the addition of the condition of competition, behaviors like those with positional values can be explained.

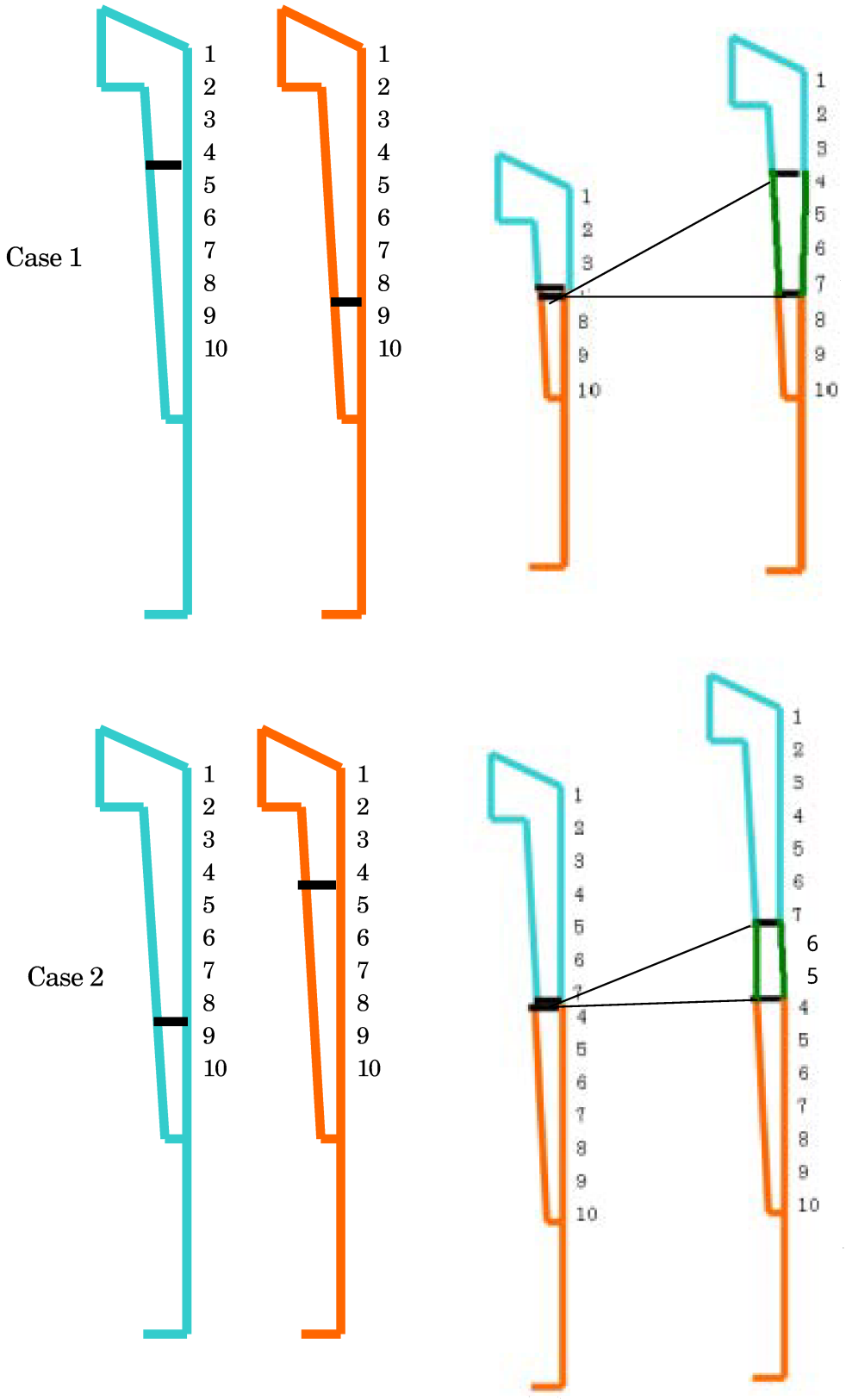

Fig.3 Experiments by legs of a cockroach (From Molecular biology of the cell (Ref. 4))
The numbers mean positional values..

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