# On the dynamics of shaping. The generalization of the morphogenesis

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*"everything that has shape can be defined, everything that can be defined can be conquered"*
*Sun Bin*

**CONTENT**



## GENERALIZATION OF MORPHOGENESIS WITHIN ONE CASE OF LARGE SCALE PHENOMENA

The mountain top line is described by all the points on its curve S. If one manages to find the movement of every point on the line S, then one should actually find the shape of the line S at any given moment in time. Let us now consider a certain point S, with the coordinates x and y, on the mountain top line, denoted by S(x,y). One can solve the system of equations for morphogenesis and find the value of speeds on both axes x and y, at any given moment in time. The shaping process of the top line, namely the speeds of the points of the mountain top line are determined by the following system of differential equations:

$$\begin{cases} a_{xr} = \dfrac{dv_{xr}}{dt} = f\left(v_{x,r}, v_{y,r}\right) + \mu\left(v_{x,r+1} - 2v_{x,r} + v_{x,r-1}\right) \\ a_{yr} = \dfrac{dv_{yr}}{dt} = g\left(v_{x,r}, v_{y,r}\right) + \nu\left(v_{y,r+1} - 2v_{y,r} + v_{y,r-1}\right) \end{cases}$$

If one takes into consideration the same simplifying case of the functions f and g considered to be linear in the respective morphogens by A. Turing, the system is then simplified to:

$$\begin{cases} a_{xr} = \dfrac{dv_{xr}}{dt} = mv_{x,r} + nv_{y,r} + \mu\left(v_{x,r+1} - 2v_{x,r} + v_{x,r-1}\right) \\ a_{yr} = \dfrac{dv_{yr}}{dt} = pv_{x,r} + qv_{y,r} + \nu\left(v_{y,r+1} - 2v_{y,r} + v_{y,r-1}\right) \end{cases}$$

The above system (3) is showing that both components of acceleration representing actually the differentials in relation with time, determined by the forces acting in the considered model are depending on the following factors: the influence of speeds on each coordinate and the diffusions caused by each morphogen in the concentrations of both morphogens, as functions depending on the double differentiation operator.

After solving it, one can know the speed of every point on the curve S and by integrating the respective speed functions over time, with the conditions of the initial coordinates of the points of line S, one can easily find the shape of the curve S, at any given moment (r) in time.

## GENERALIZATION OF MORPHOGENESIS WITHIN ONE CASE OF VERY SMALL SCALE PHENOMENA

In both cases the particles are subjected to one single probability wave function Ψ. For the case of two interacting particles x and y, their corresponding n positions ($x_i$, $y_i$), i from 1 to n, are given by the probability wave function:

$$\Psi(x, y, t) = e^{-iEt/\left(\frac{h}{2\pi}\right)}$$

If we take into consideration the process of morphogenesis, the system describing the shapes resulting from the interaction of the respective quantum particles has the following form:

$$\begin{cases} \dfrac{d\Psi(x_r, y, t)}{dt} = e^{-iEt/\left(\frac{h}{2\pi}\right)}\Psi(x_r, y) + \mu\left(x_{r+1} - 2x_r + x_{r-1}\right) \\ \dfrac{d\Psi(x, y_r, t)}{dt} = e^{-iEt/\left(\frac{h}{2\pi}\right)}\Psi(x, y_r) + \nu\left(y_{r+1} - 2y_r + y_{r-1}\right) \end{cases}$$

The system above is exhibiting the same general form of the morphogenesis equations system, which has already been presented.

## GENERALIZATION OF MORPHOGENESIS FOR THE CASE OF (N) MORPHOGENS

The generalization in this chapter is presented going out from the assumption that all the conditions imposed by the existence of the process of morphogenesis are fulfilled and the morphogens and their interactions have been identified. The system of equations for the morphogenesis for n interacting morphogens thus identified has the form:

$$\begin{cases} \dfrac{dx_1}{dt} = a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n + \mu_1(\Delta x_{1,r+k}) \\ \dfrac{dx_2}{dt} = a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n + \mu_2(\Delta x_{2,r+k}) \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \dfrac{dx_j}{dt} = a_{j1}x_1 + a_{j2}x_2 + \cdots + a_{jn}x_n + \mu_j(\Delta x_{j,r+k}) \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \dfrac{dx_n}{dt} = a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n + \mu_n(\Delta x_{n,r+k}) \end{cases}$$

The above generalization is made, taking into account some simplifying assumptions, such as:

a) The functions of dependence between the variations of speed of the concentrations of the respective morphogens from above alongside with their diffusion rates, which are functions of difference operators for each of the morphogens, are considered for (n) different morphogens.

b) The functions of concentrations of morphogens are deemed to be linear in the respective morphogens.

c) The diffusion rates, which are functions of difference operators can be difference operators, not only of second order, but of any higher order difference operators.

## CONCLUSIONS

The present paper analysis whether and to what extent the process of morphogenesis could be generalized and what conditions are to be fulfilled so that the generalizations take place. It is taking into consideration the dynamic of fractals, that is to say the evolution of fractals' shapes, based on underlying factors (morphogens) generating the respective shaping process of the fractals. One other way to deal with the dynamics of shaping process in the fractals, based only on the fractals' shapes coordinates evolving in time, is presented in the other paper of the author, within the same Conference.

The theory of morphogenesis, as proposed by A. Turing can be generalized for large scale and very small scale phenomena, under the assumption that the random physical quantity that is accountable for the shaping process and changes over time can be made dependent on its variation in time.