Title	A traveling wave surviving through an environmental change : Adaptation on an Excitable Field
Author(s)	Tanaka, Masanobu; Nagahara, Hiroki; Kitahata, Hiroyuki
Citation	(2006), 87(1): 129-130
Issue Date	2006-10-20
URL	http://hdl.handle.net/2433/110614
Right	
Type	Departmental Bulletin Paper
Textversion	publisher

A traveling wave surviving through an environmental change
- Adaptation on an Excitable Field -

Dept. of Physics, Kyoto Univ.

Masanobu Tanaka [1] ,Hiroki Nagahara and Hiroyuki Kitahata

興奮波は自然界の中に多く見られる現象である。本研究では、環境変化に対する興奮波の "適応" について調べた。興奮波の代表的な実験系である光感受性 BZ 反応では、照射する光の強度で興奮性を容易に変えることができる。この実験系において、照射する光の強度を突然大きくするという急激な環境の変化に対して、興奮波が適応できず伝播失敗することが分かった。2 変数 Oregonator を用いた数値実験でこの現象を再現するとともに、そのメカニズムを議論する。

1 Introduction

It is well known that characteristics of excitability can be found in a wide variety of nature, including nerve membranes, heart tissue and the Belousov-Zhavotinsky (BZ) reaction.[1] In the present research, we investigate the "adaptation" of an excitable wave to an environmental change. We adopted a light-sensitive BZ reaction using ruthenium (Ru) catalysts as an experimental system. In this chemical system, illumination results in the production of bromide, which inhibits the oscillatory reaction. Thus, the excitability can be adjusted by changing the light intensity. In this system, we found that single wave fails to propagate when the light intensity increases abruptly. We reproduced the experimental trends by the numerical experiment using a two-variable Oregonator. It is found that the manner of propagation critically depends on the time course on the increase of the inhibitory effect.

2 Experiment and Numerical Simulation

Figure 1 a) shows a snapshot of the actual experiment. In Figure 1 a), the gray region is illuminated at 15000 lux, where wave propagation is inhibited. On the other hand, the two black regions (R1,R2) are illuminated at 560 lux, where a wave can propagate. We changed the light intensity from 560 lux to 5250 lux more slowly in R1 than in R2; the time span of change is 70 sec and 0.1 sec in R1 and in R2, respectively. Figure 1 b) shows the space-time plot of a single propagating wave in R1 and R2. In Figure 1 b), the wave under the gradual change (R1) survived. On the other hand, the wave under the abrupt change (R2) disappeared.

In order to investigate the underlying mechanism, we used the Oregonator model which was modified for the light-sensitive BZ reaction. The parameter ϕ gives the light-induced production of Br^- ,which is proportional to the light intensity. Similar to the experiment, ϕ increase slowly or abruptly. The parameter T corresponds to the time span during which light intensity is changed from ϕ_{min} to ϕ_{max}.

$$\frac{\partial u}{\partial t} = D_u \nabla^2 u + \frac{1}{\epsilon} \left\{ u(1-u) - (fv+\phi)\frac{u-q}{u+q} \right\} \tag{1}$$

$$\frac{\partial v}{\partial t} = D_v \nabla^2 v + u - v \tag{2}$$

---

[1] E-mail:tanaka-m@chem.scphys.kyoto-u.ac.jp

$$\phi(t) = \begin{cases} \phi_{\min}(0 \leq t \leq t_{\text{int}}) \\ \phi_{\min} + \frac{\phi_{\max} - \phi_{\min}}{T}(t - t_{\text{int}})(t_{\text{int}} \leq t \leq t_{\text{fin}} : t_{\text{fin}} = t_{\text{int}} + T) \\ \phi_{\max}(t \leq t_{\text{fin}}) \end{cases}$$

Figure 2 shows the results of the numerical simulation. We use an order parameter S (defined as a size of wave measured with activator) to examine the dynamics of wave. In Figure 2, the dotted line under the abrupt change (T=1.2) falls to 0 ,while the dashed line under the slow change (T=2.8) reaches to $S_{\phi_{\max}}$ (solid line). The experimental data were compared with numerical results. We will also discuss the effect of the time course of the environmental change on the excitability in relation to the "adaptaion" which is general in the sensation of living organisms.
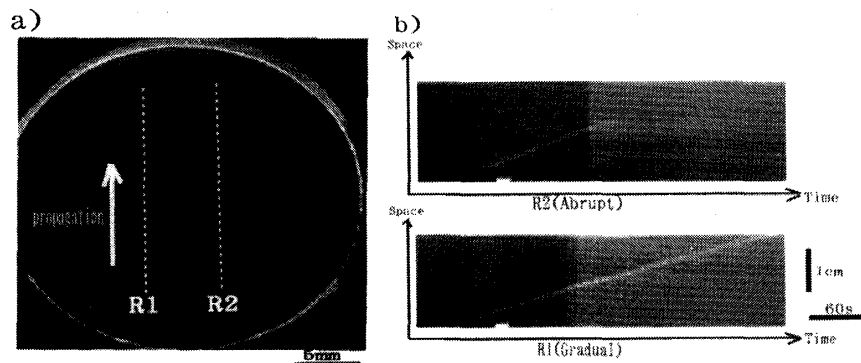

Figure 1: a) Experimental System: R1 and R2 are the regions where a wave can propagate. b) Space-Time plot of wave propagating through R1 and R2 : We changed the light intensity more gradually in R1 than in R2.
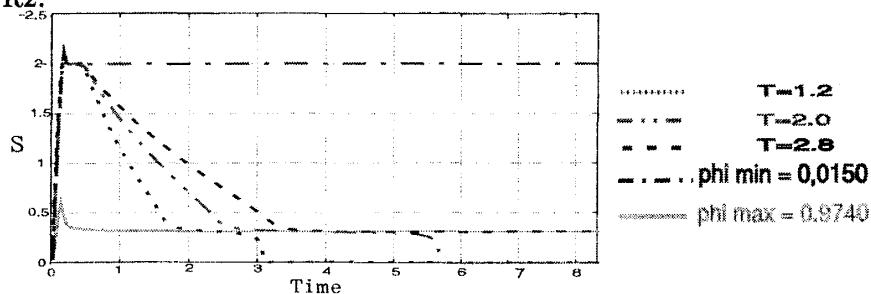

Figure 2: Change of S for various T
S is defined as a size of wave. T corresponds to the time span of change.

Acknowledgment

References

[1] J.D.Murray,*MathematicalBiology* (Springer,Berlin,1990).