INTRODUCTION

A variety of room-temperature aqueous solutions colorfully exhibit in two and three dimensions the excitability, signal transmission, and spontaneous oscillation more familiarly associated with biological media such as aggregating slime molds, rhythmic fungi, nerve, heart, and intestinal smooth muscle. I will refer to these chemical solutions collectively as "Z reagent" in honor of their chief developers, A. M. Zhabotinsky and A. N. Zaikin (1970). Because Z reagent is so convenient to prepare and study, it is tempting to employ it as a heuristic tool in seeking consequences of oscillation and excitability which may have escaped attention during technically more difficult experiments in living systems. My belief is that observations on Z reagent suggest at least one unexplored mode of solution to the partial differential equations used to describe excitable media, which may merit the attentions both of mathematicians and of biologists.

Accordingly, I take this opportunity for a brief survey of Z reagent behavior, emphasizing analogies to biological media. I will try to cite as much recent literature as feasible since the pertinent journals and symposia are usually found in separate rooms of the library.

In a nutshell, Z reagent is a colored solution which develops moving red and blue bands. For accounts of the chemical basis of this spatially-patterned reaction see Field, Körös, and Noyes (1972; Field and Noyes (1972; Field (1972). In studying the moving patterns, I find it useful to distinguish "pseudo-waves" from "trigger waves" (or "waves"), and to distinguish two kinds of trigger-wave source: "target" nuclei, and a rotating dissipative structure that I will call a "scroll core" or when appropriate, a "scroll ring". In making these distinctions I am struggling
to clarify in my own mind a point of particular confusion (as I see it) in the
current literature: that several theoretical models of Z waves have been stimulated
by observations on trigger waves, but in fact describe pseudo-waves.

**PSEUDO-WAVES**

Several models have appeared in the literature surrounding Z reagent, which
thoroughly develop the properties of what I (1972) call pseudo-waves, Kopell and
Howard (1973) call kinematic waves, Ortoleva and Ross (1973) call phase waves, etc.
These are the visible expression of shallow concentration gradients which result
in gradient of *timing* of a limit cycle oscillation parochially pursued in each
volume element of the medium ---- like the pseudo-wave of traffic-light switching
that gates traffic along major avenues in a city. Pseudo-waves of nearly
synchronous mitosis are familiar in diverse organisms e.g. Physarum (Cohen (1972)).
Pattern polymorphism in a growing fungus has been described as a consequence of
shallow phase gradients in a sheet of nearly independent limit-cycle oscillators
(Winfree (1970), (1973)). Following the lead of Beck and Varadi (1972), Kopell and
Howard (1973), Smoes and Dreitlein (1973) and Thoenes (1973) have modelled Z
reagent in this way, additionally allowing phase gradients to *increase* due to a
spatial gradient in some parameter (e.g. temperature) which governs the period of
local oscillation. By an elegant experiment Kopell and Howard (1973) and Thoenes
(1973) independently confirmed the claim of Beck and Varadi (1972) that the
horizontal color bands which appear in a vertical column of Z reagent (Busse (1969))
in some cases constitute not a dissipative structure as in Herschkowitz-Kauffman
(1970), Glansdorf and Prigogine (1971), but pseudo-waves organized by a vertical
gradient of temperature or chemical concentration.

Ortoleva and Ross (1973) have constructed a more detailed theory of phase
gradients modified by diffusion near a heterogeneity.

In Z reagent, pseudo-waves are characterized by four features:

1) Velocity depends on position and can be arbitrarily large; given $\phi = \phi(x,t)$,

$$\text{velocity} = \frac{\partial x}{\partial t} |_{\phi} = -\frac{\partial \phi}{\partial t} / \frac{\partial \phi}{\partial x} = -2\pi / \tau \frac{\partial \phi}{\partial x}$$
in the direction of the