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Rapid Regulatory Control of Plant Cell Expansion and Wall Relaxation

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The aim of this project is to elucidate the biophysical and cellular mechanisms that control plant cell expansion. At present we are attempting to characterize the kinetics of the system(s) responsible for regulatory and compensatory behavior of growing cells and tissues. This work is significant because it indicates that biochemical loosening and biophysical stress relaxation of the wall are part of a feedback loop controlling growth. This report briefly summarizes the efforts and results of the past 12 months. In large part, we have been trying to analyze the nature of growth rate "noise", i.e. spontaneous and often erratic variations in growth rate. We are obtaining evidence that such "noise" is not random, but rather reveals an underlying growth mechanism with complex dynamics. In addition to the report below, two reprints and one manuscript are attached.

1) Instrumentation and methods development. The software for driving the computer-controlled pressure-block device has been refined for better control and extended to allow more complex test patterns. By use of pressure-sinusoid, we should be able to analyze wall-yielding properties in a much more flexible fashion than hitherto was possible. The acquisition, storage and analysis of growth rate information has also been vastly improved. We can now routinely "massage" growth rate records by Fourier frequency decomposition, phase plotting, and statistical methods for more potent analysis of growth dynamics.

Video analysis of local growth rate patterns along the growing stem has been developed to the point where we can begin to dissect migrating growth waves from non-migrating growth pulses. Such spatial and temporal information is essential for

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formulating biochemical and cellular models of the growth-regulatory mechanism. For example, if auxin were involved, one might expect under some conditions to see migrating growth waves with a velocity similar to that of basipetal auxin transport. On the other hand, other growth mechanisms could cause temporal growth pulses without spatial movement.

2) New insights into "random" growth rate patterns. Although plants have previously been shown to exhibit large, erratic variations in growth rate, the nature and meaning of these variations have been largely ignored and remain a mystery. Using a new nonlinear forecasting method to analyze growth records, I found that the pattern of these spontaneous growth fluctuations is consistent with an underlying dynamical system that gives rise to "deterministic chaos". Experimental manipulation of growth by step or sinusoidal variations in external pressure (pressure-block) indicates that growth is controlled by a nonlinear feedback system which exhibits time lags, resonance, frequency-dependent harmonic responses and period doublings. Moreover, 3/4 of the growth rate "noise" can be eliminated by entrainment of the feedback system with a pressure sinusoid. The results indicate a complex control mechanism which may serve to coordinate wall expansion with other processes required for cell growth and under some conditions may give rise to multicellular effects such as nutation and related oscillatory phenomena in plant growth.

3) Coupling of solute uptake with cell expansion. Work we published last year showed that when water uptake into expanding pea stems was prevented hydraulically (using the pressure-block method), the unloading of phloem solutes into the expanding region stopped simultaneously. We extended these observations in a series of experiments with cucumber seedlings. We found that solute-growth coupling also occurs in these plants during growth responses to auxin and gravity. The evidence points further to a growth model in which phloem unloading is tightly coupled to water uptake, perhaps through a bulk-flow of solutes and water through the plasmodesmata.

Publications related to this project:

1) Kigel, J. and D.J. Cosgrove. 1991. Photoinhibition of stem elongation by blue and red light: effects on hydraulic and cell wall properties. *Plant Physiology* 95: 1049-1056 (reprint attached)

- 2) Cosgrove, D.J and R. Hedrich. 1991. Three stretch-activated ion channels coexist in the plasma membrane of guard cells. *Planta* (submitted)~~✖~~
- 3) Moore, P.H. and D.J. Cosgrove. 1991. Developmental changes in cell and tissue water relations parameters in storage parenchyma of sugarcane. *Plant Physiology* 96: 794-801 (reprint attached)~~✖✖~~
- 4) Cosgrove, D.J. Chaos, oscillations and feedback in plant growth. (Submitted to *Science*; ms attached)~~✖✖~~

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