Plant Cell Expansion and Plant Hormones

# Introduction

Plants are capable of rapidly adapting to changes in their environment. Plants can grow to replace damaged parts, bend in the direction of light cues, or elongate rapidly under good conditions. Plant hormones often play a role in plant development by affecting patterns of growth. Gibberellins, in particular, can elicit changes in growth, elongation, and flowering.

The growth of a plant cell is primarily driven by the uptake of water into the cytoplasm and vacuole of the plant cell. The vacuole expands rapidly, pressing against the cell wall. In order for the cell to enlarge, the cell wall must yield to the stress produced by cell turgor. Therefore, we would suspect that plant hormones might affect properties of the cell in order to affect plant growth.

# Importance

We can use simple equations to model cell enlargement. By comparing experimental data to models, we can determine what factors affect cell enlargement and how plant hormones affect these factors.

# Questions

How do osmotic potential and properties of the cell wall contribute to cell enlargement? How do plant hormones affect rates of cell enlargement?

# Variables

|  |  |
| --- | --- |
| G | steady state growth rate of a cell (% change/hr) |
| L | hydraulic conductivity of cell (bar-1hr-1) |
| f | wall extensibility (bar-1hr-1) |
| s | solute reflection coefficient (dimensionless) |
| P1, P2 | osmotic potential on the outside and inside of cell (bar) |
| Y | yield threshold (bar) |

# Methods

The growth rate of a plant cell depends on the amount of water uptake and the capacity of the cell wall to extend. Consequently, the growth rate of a plant cell, or % change in cell volume per hour, can be described by the following equation:

|  |  |
| --- | --- |
| $$G=\frac{Lf}{L+f}\left(s\left(P\_{2}-P\_{1}\right)-Y\right)×100\%$$ | LaTeX Code: \[ G = \frac{Lf}{L+f} (s(P\_2 - P\_1) - Y) \times 100 \% \] |

where L is the hydraulic conductivity of the cell, f is cell wall extensibility, s is the solute reflection coefficient, (P1-P2) is the difference in osmotic potential across the membrane, and Y is the minimum turgor pressure required to initiate cell expansion. The hydraulic conductivity (L) reflects the permeability of the cell to water related to the surface area and volume of the cell. Wall extensibility (f) depends on the thickness and properties of the cell wall.

Osmotic potential (Pi) reflects the the pressure required to stop the net flow of water across the plant cell membrane. When the osmotic pressure inside of the cell (P2) is larger than that outside of the cell (P1), water flows into the cell. Notice when s(P2-P1)=Y, the cell does not grow. In other words, the minimum turgor pressure required to initiate cell expansion has not been met.

We can plot the enlargement rate of a plant cell (G) as a function of wall extensibility (f) for two different values of osmotic potential (s(P2-P1)). We take L = 0.02 bar-1 hr-1, and Y = 2 bar.



Notice that the growth rate of the cell (G) increases quickly as we increase wall extensibility (f). Growth rate eventually levels off, however, depending on the osmotic potential of the cell. In other words, no matter how flexible the cell wall is, a high cell growth rate depends on a high influx of water into the cell.

We can also plot the enlargement rate of a plant cell (G) as a function of the difference in osmotic potential across the membrane (s (P1-P2)) for two different values of cell wall extensibility (f). We take L = 0.02 bar-1 hr-1, and Y = 2 bar.



As long as the cell wall extensibility is fairly high, the growth rate of the cell increases linearly with its osmotic potential or the influx of water into the cell. The slope of this line depends on the extensibility of the cell wall (f) as well as its water permeability (L). As f increases, the growth rate of the cell increases.

# Interpretation

**Plant Hormones:** We can use similar curves to understand how the growth hormone gibberellin operates. Researchers hypothesized that gibberellin increases growth rate by changing the osmotic potential of the cell. By secreting solutes into the cell (increasing P2), the growth rate of the cell would increase. However, if we plot curves of G as a function of f for plant cells with and without gibberellin, we find the curves are quite similar (even more similar than in the first figure). This indicates gibberellin has little effect on osmotic potential of the cell. Researchers found that the hydraulic conductivity (L) and the solute reflection coefficient (s) also were unaffected by gibberellin. The logical hypothesis is that gibberellins affect the cell wall extensibility (f).

We can plot G as a function of s (P1-P2) for plants with and without gibberellin. We find curves similar to that in the second figure (above). We can interpret this large increase in slope to mean that gibberellins are causing a large increase in cell wall extensibility (f). In fact, gibberellins may act by breaking polymer bonds within the cell wall or increasing the synthesis of cell wall polymers.

# Conclusion

The enlargement of plant cells depends on the influx of water into the cell and the ability of the cell to yield to this stress. Researchers can use models of cell enlargement to examine how plant hormones and environment properties affect osmotic potential, cell wall extensibility, or cell turgor, and consequently affect cell enlargement.

# Additional Questions

1. For the plot of G as a function of f, algebraically determine the horizontal asymptote. How do you interpret this biologically?

2. For the plot of G as a function of s (P1-P2), determine the x-intercept and the slope. How do you interpret this biologically?

# Source

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# About this Resource

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This material is now being revised as part of the “Resources for Improving Quantitative Skills in Community College Biology[[2]](#endnote-2)” project. As part of that project is also aligned with the OpenStax Biology Textbook[[3]](#endnote-3).

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