Quantifying a 3D Shape By Translating It Into a 2D System for Intuitive Visualization

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Intuitive Visualization of a 3D Object in 2D:

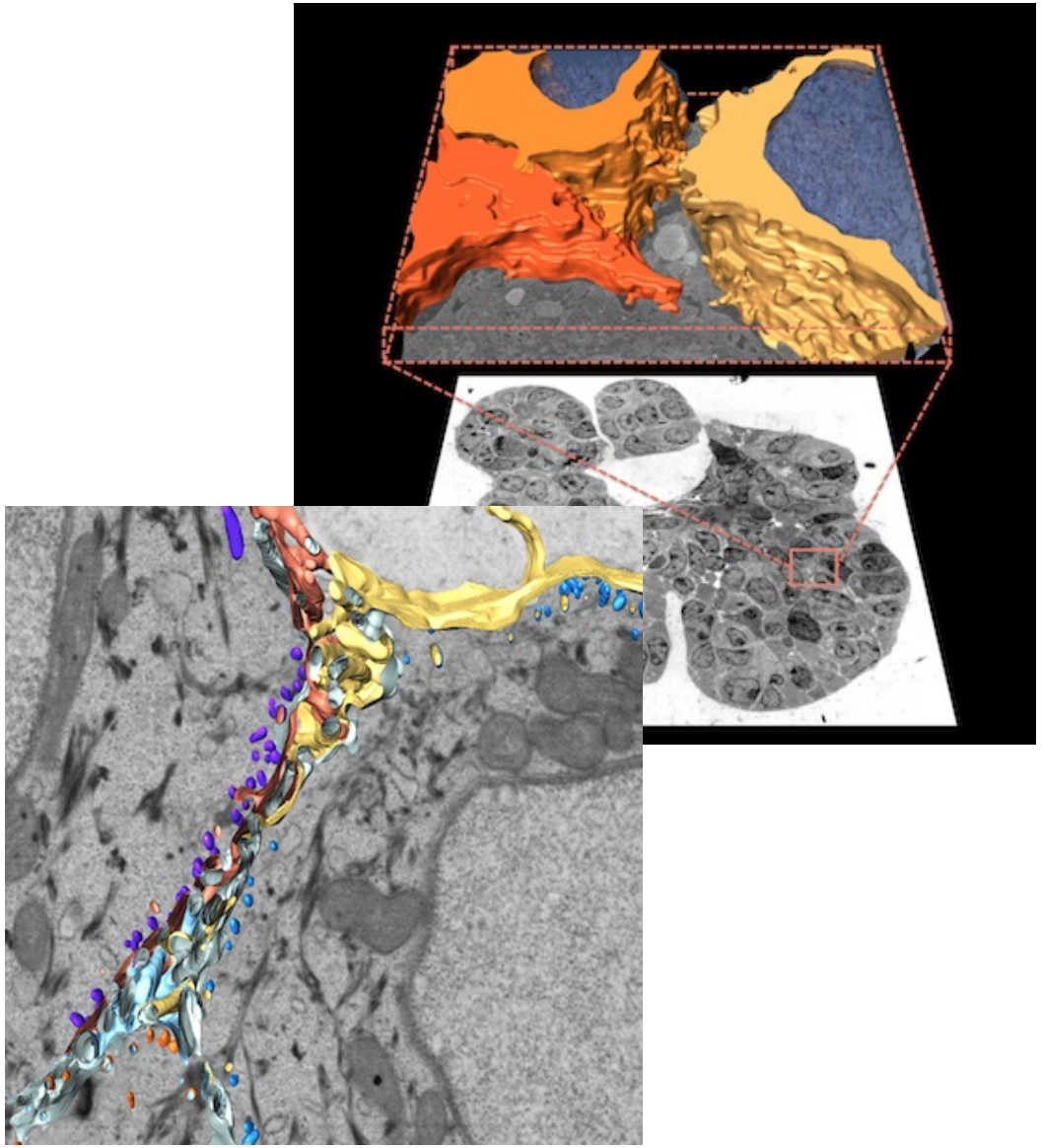
The Planarized Globe Plot (PGP) Transformation

Problem Statement

How can we simplify the complexity of a 3D system into a 2D system that is:

1) More comprehensible to scientists who are used to interpreting 2D graphs.
2) And allows for quantitation of spatial arrangements via statistical rigor (i.e. correlation).

3D Mammary Organoids Reconstructed from Electron Microscopy



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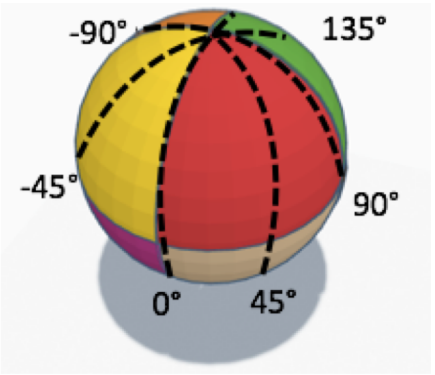
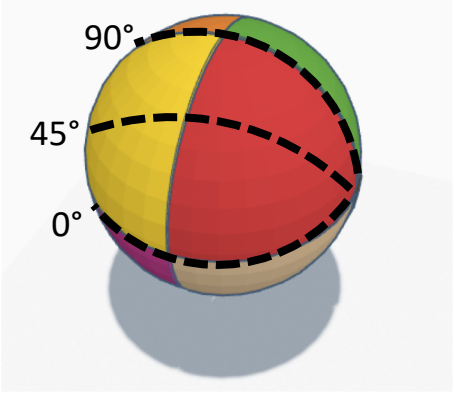
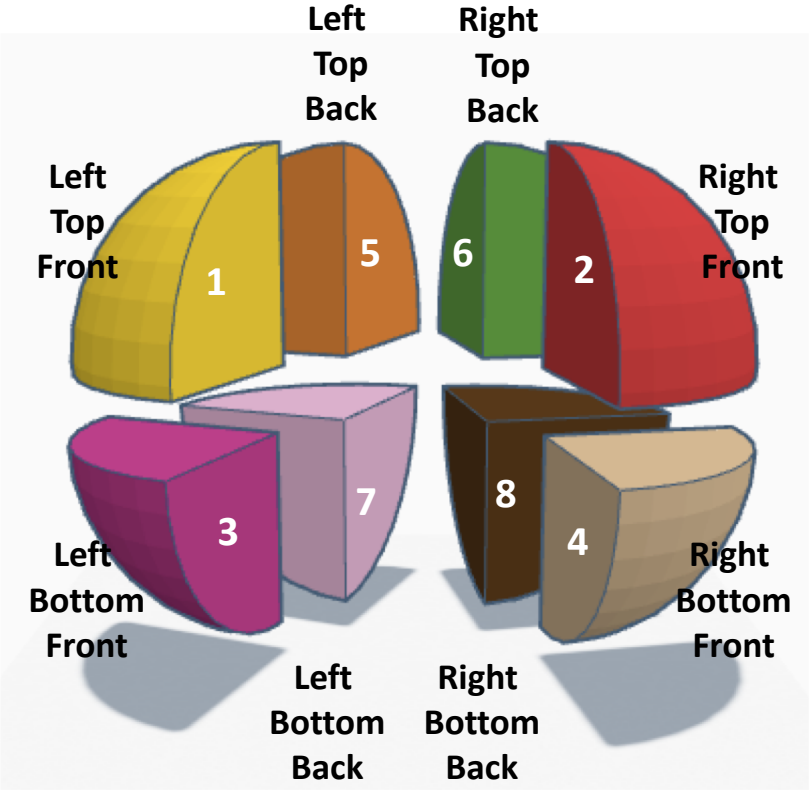
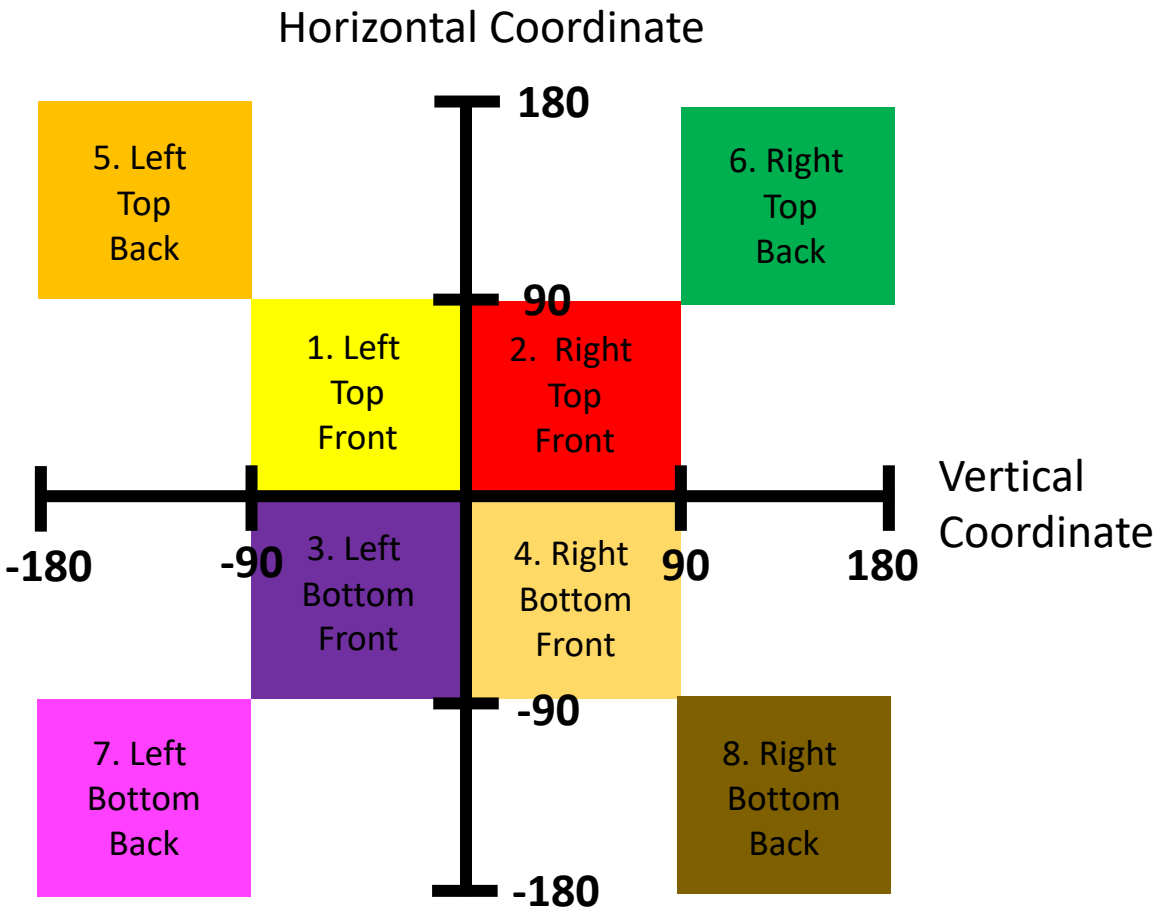






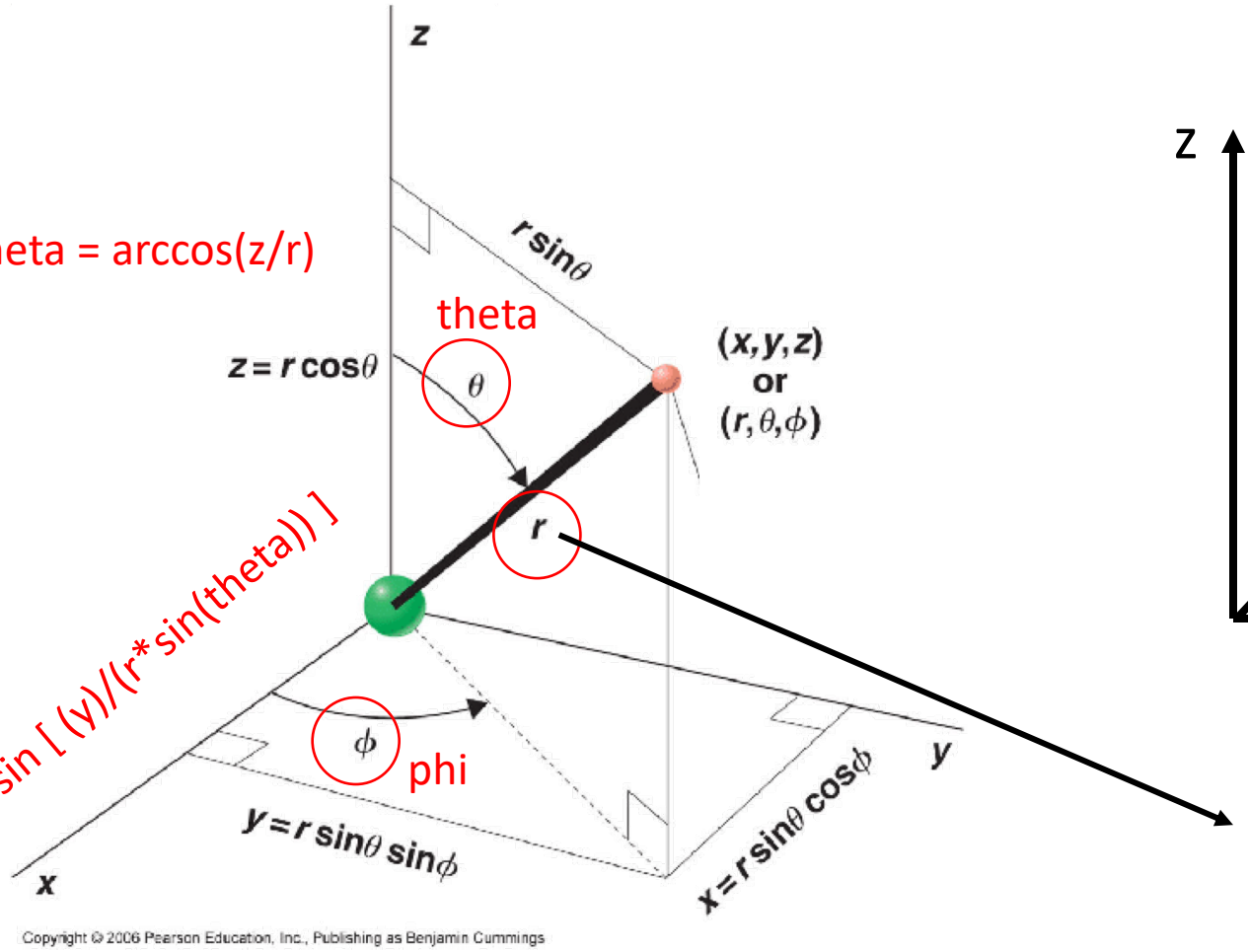
A 2D System to Visualize a 3D System

- 1st Dimension: X-axis (Vertical Coordinate)
- 2nd Dimension: Y-Axis (Horizontal Coordinate)
- 3rd Dimension: Color intensity or marker size.

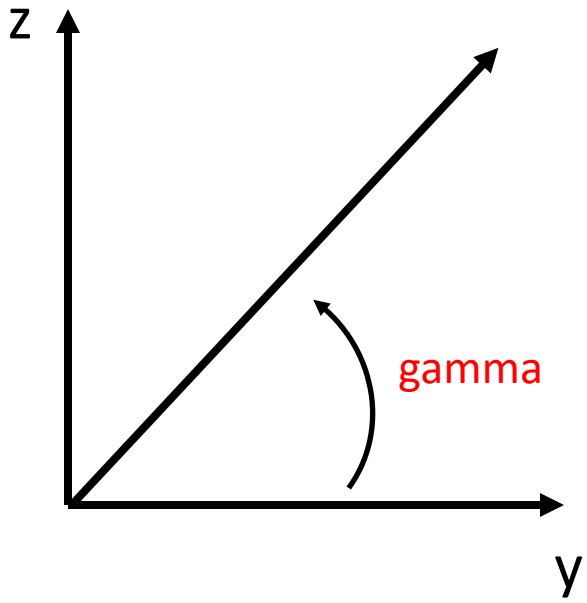


First, we need to change the (x,y,z) coordinates into angle measures and a vector magnitude. We need to calculate r, then theta, then phi. And then we calculate gamma. See below diagrams.
[The Planarized Globe Plot uses phi and gamma as the x and y coordinates, respectively.]

theta = arccos(z/r)



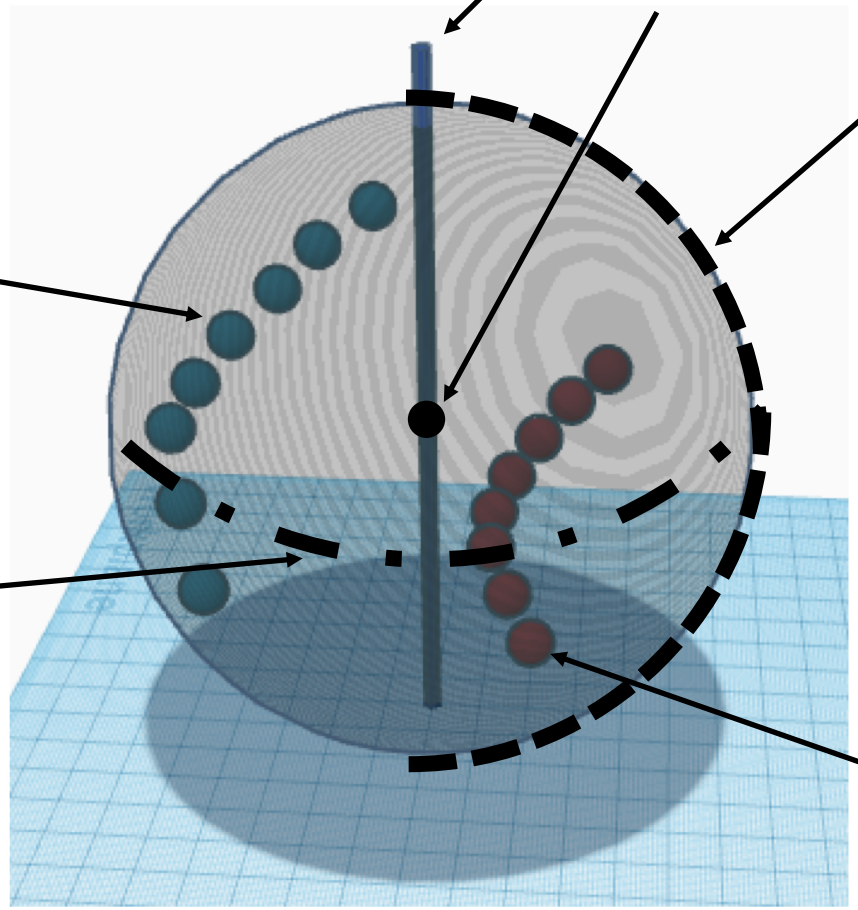
phi = arcsin [(y)/(r*sin(theta))]

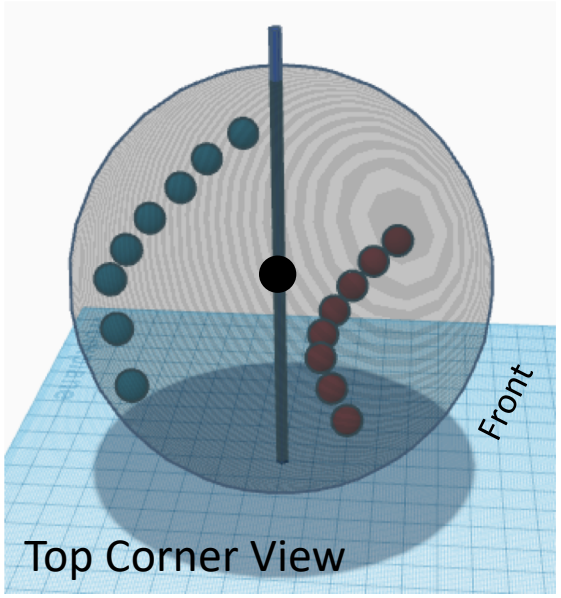


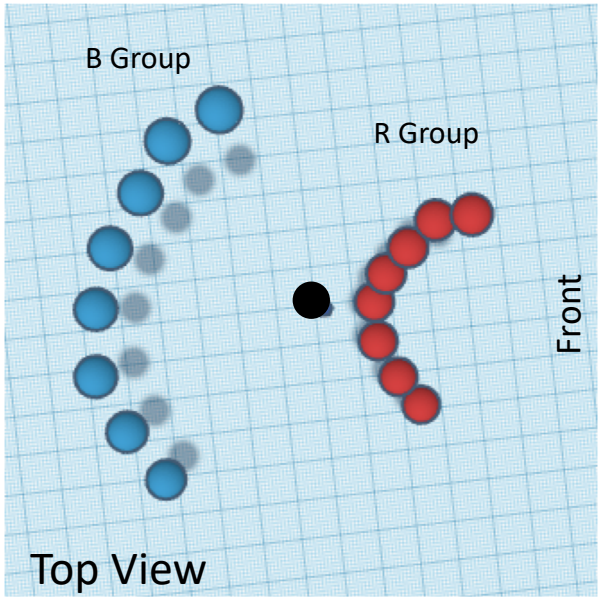
tan(gamma) = (z/y)
So, gamma = arctan(z/y)

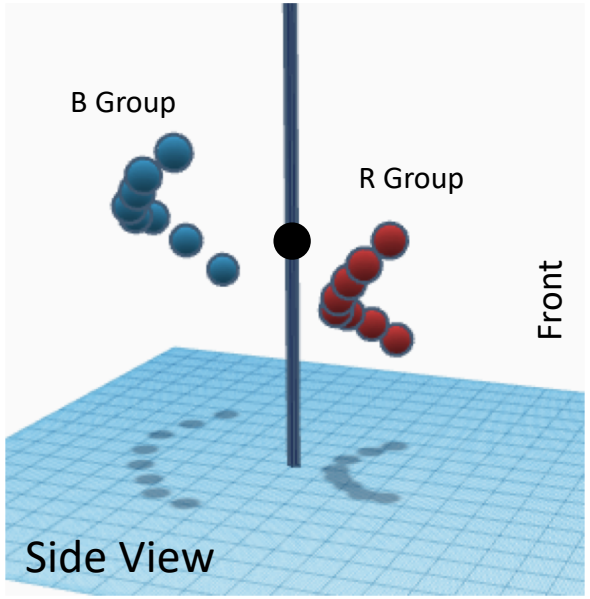
r = SQRT[(x1-x2)^2 + (y1-y2)^2 + (z1-z2)^2]

Hypothetical Cell in 3D









Legend

Distance from Center

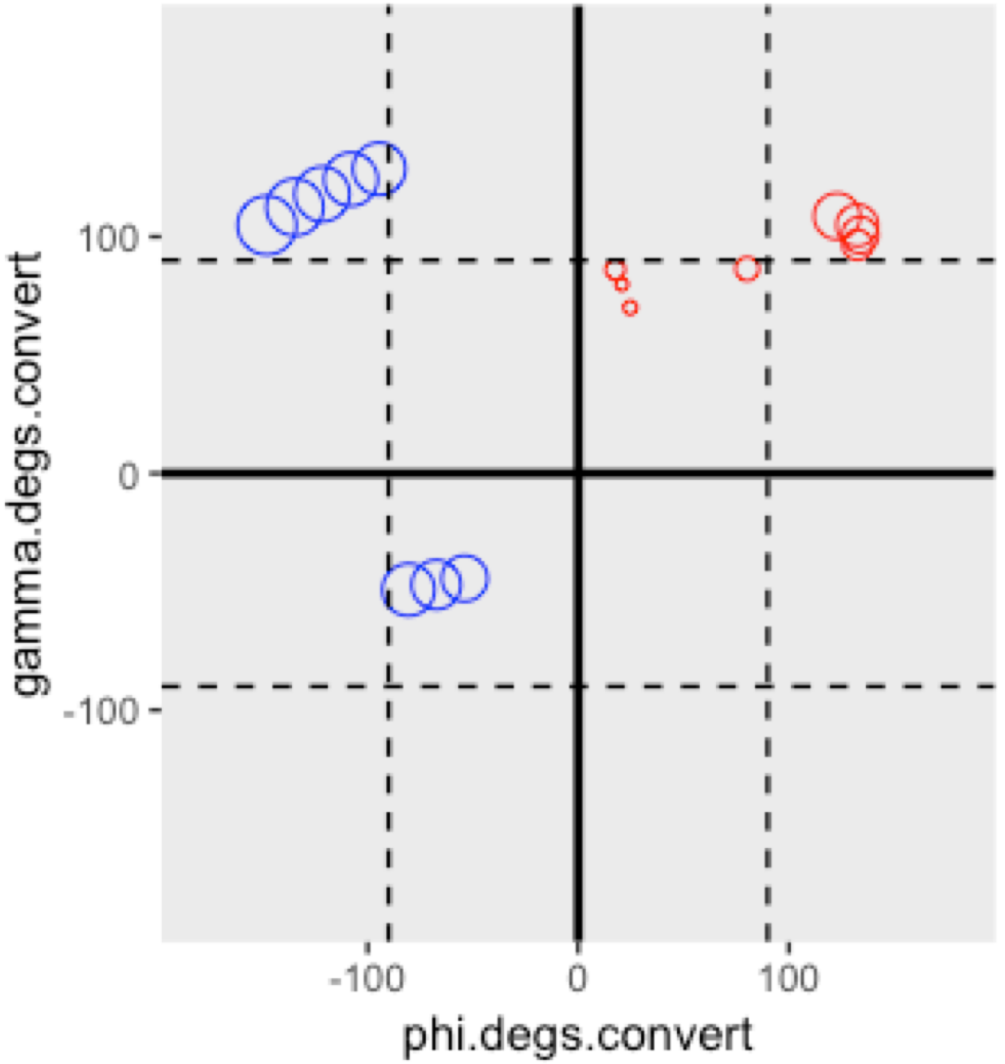
Far

Close

B Group

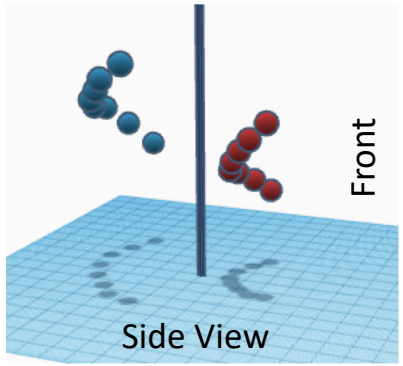
R Group

PGP Plot

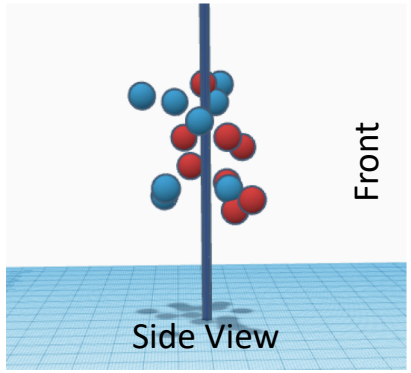


A Cartoon of “Epithelial to Mesenchymal Transition” (EMT)

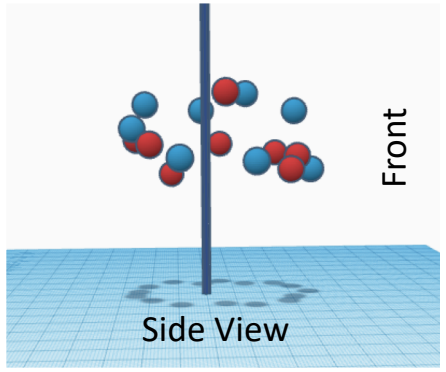
Complete Polarity



Early EMT

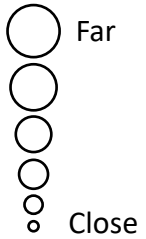


Late EMT



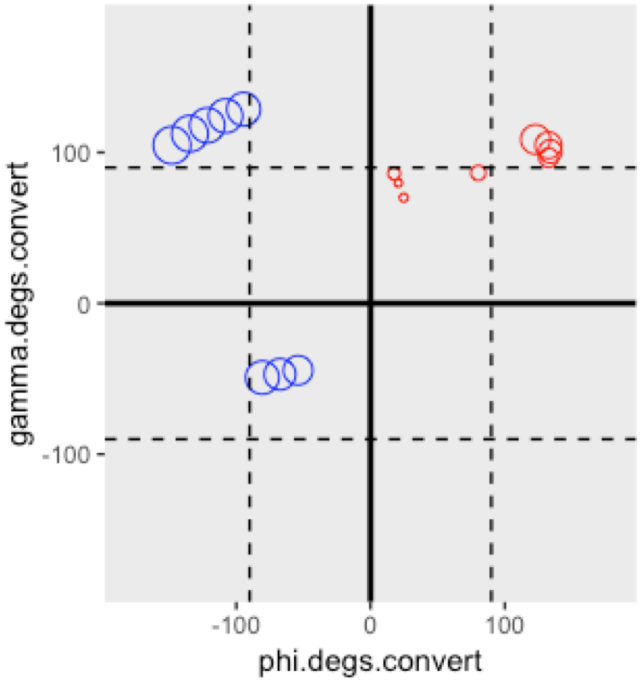
Legend

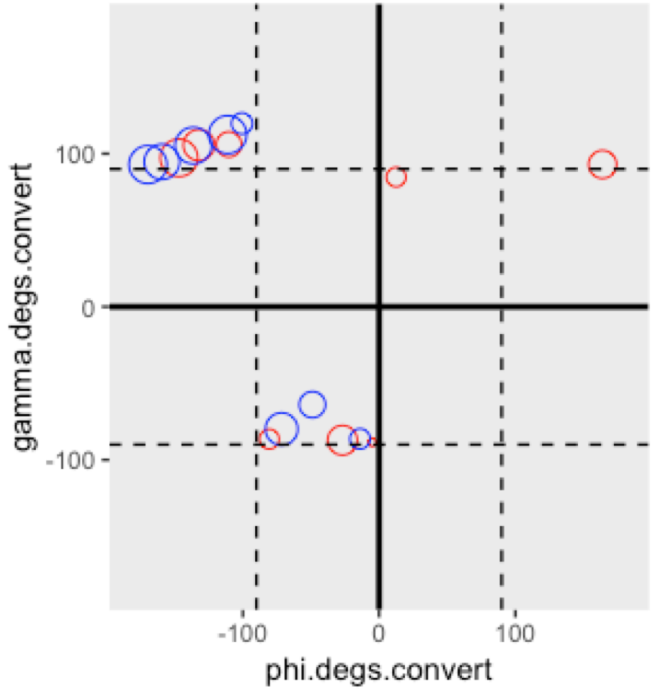
Distance from Center

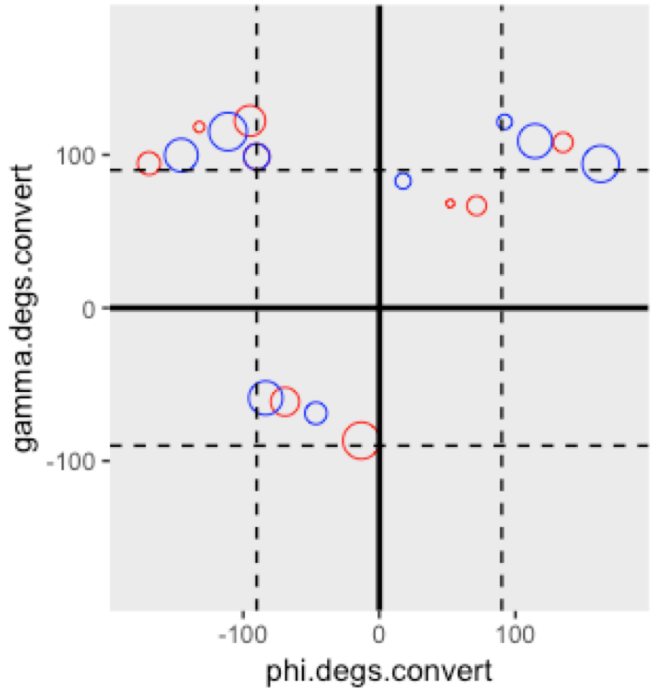


B Group

R Group







Blues and Reds plotted separately

Legend

Distance from Center

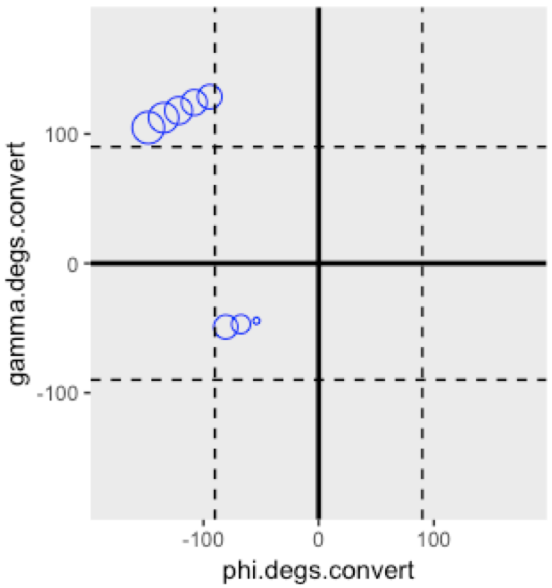
Far

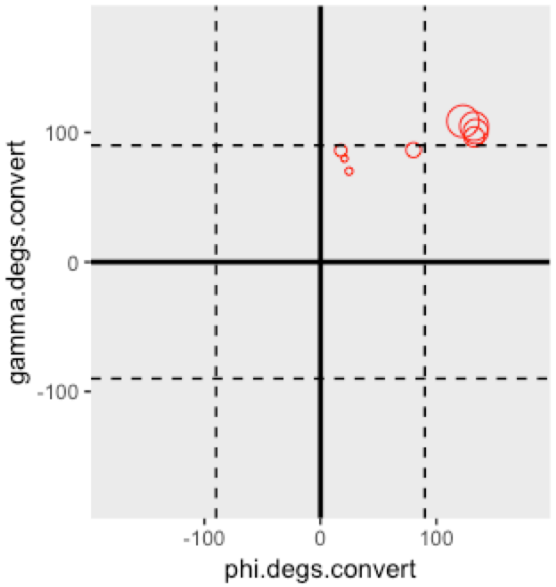
Close

B Group

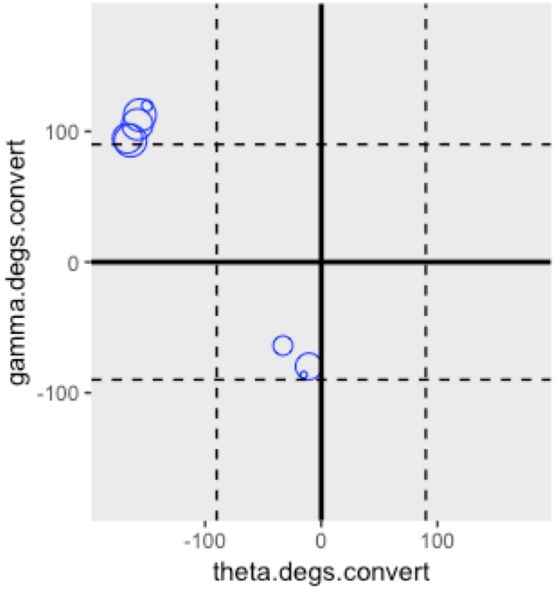
R Group

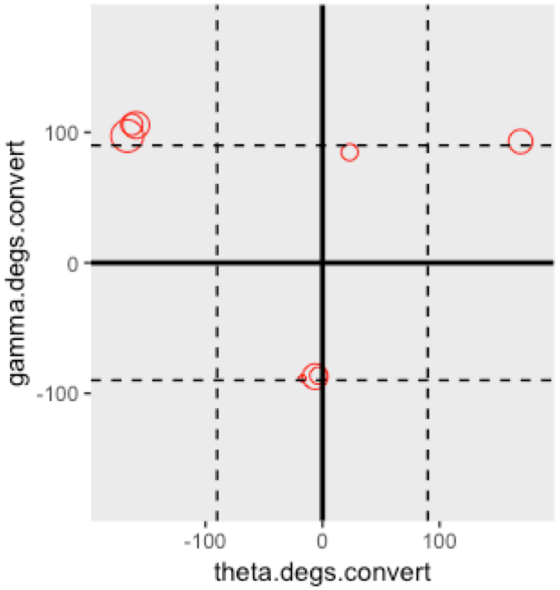
Complete Polarity



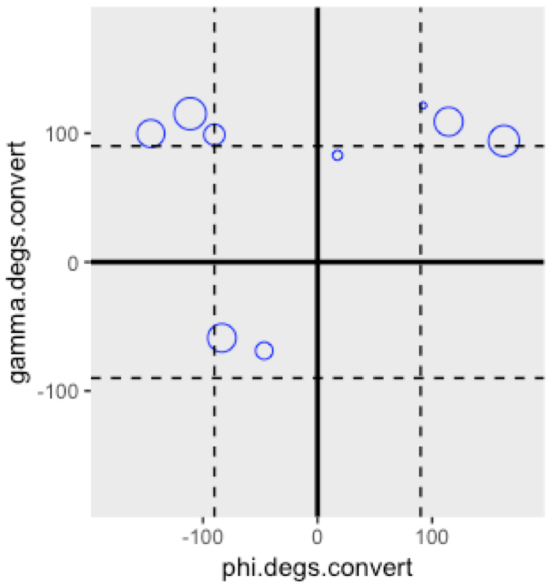


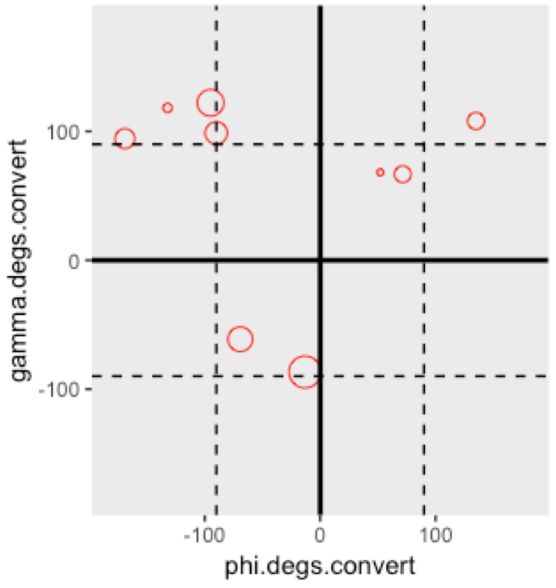
Early EMT





Late EMT





Note:
The PGP Transform does NOT require that the 3D object be spherical or round. It also does not require that the features within the 3D object be spheres (i.e. the red and blue balls). These cartoon shapes were used for simplicity of illustration.

Important Considerations

1. How to define the “center” of a cell?
    a. Nucleus is most obvious visual marker but is not always in the center of the cell. The center of mass of the nucleus may be a meaningful “center” of the cell. However, in cases such as apoptosis and mitosis, the nucleus changes dramatically over time.

2. How to define the “front” edge of a cell?
    a. Cells have polarity (basement membrane, apical surface).

3. How to define the ”front” edge of a cell that is in a 3D tissue/organoid structure that has polarity (luminal surface, basal surface)? The method outlined in this presentation can be applied to whole organoid/tissue systems to locate each cell.

4. How to normalize the magnitude (distance from ”center” to a point) for meaningful representation of relative distance between objects in the cell/system? (This refers to the size or color intensity of the marker in the 2D plane.)