Segmenting Early Embryogenesis in *Caenorhabditis elegans*

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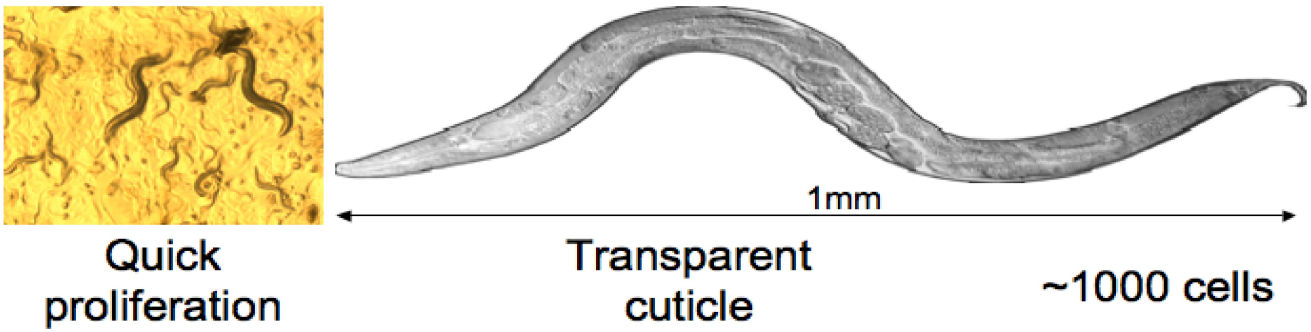
MATHBIO
Truman Mathematical Biology Program

Outline

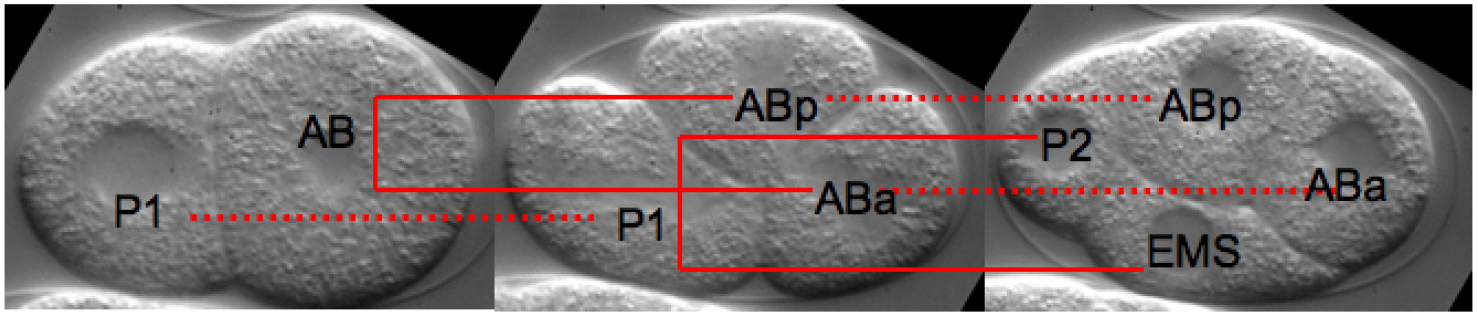
Segmenting Early Embryogenesis in *C. elegans*

C. elegans as a Developmental Model



- Rapid period of embryogenesis (16 hours).
- Easily maintained in large quantities.
- Predominant adult form is hermaphroditic and capable of self-fertilization.
- Transparent eggshell allows observation of all stages of embryogenesis.

C. elegans as a Developmental Model



- *C. elegans* have an invariant cell lineage that gives rise to only 959 somatic cells.
- *C. elegans* has a compact genome while still having a comparable number of genes with humans.

	# of Genes	Estimated Genome size (bp)
C. elegans	20,178	100,267,623
H. sapiens	~24,000	3,244,750,000

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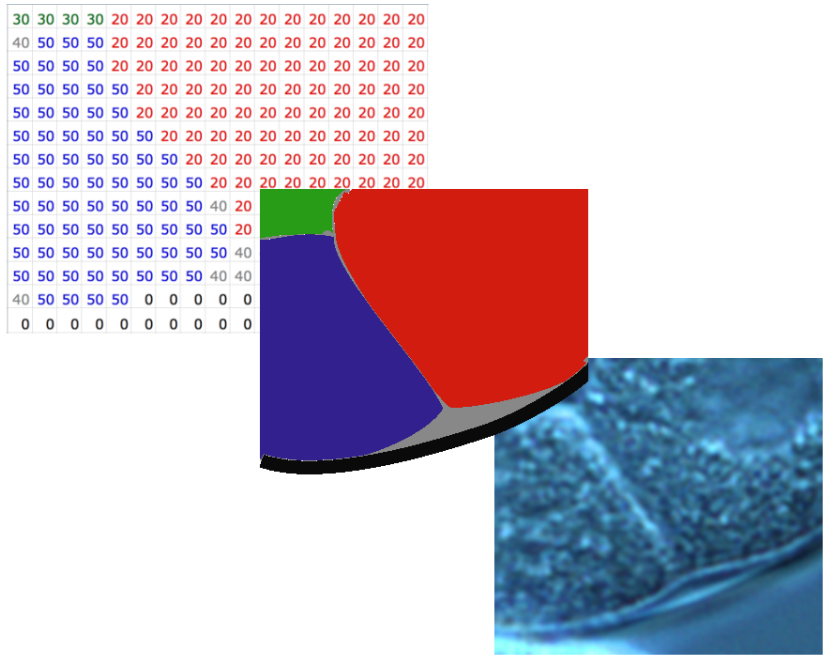
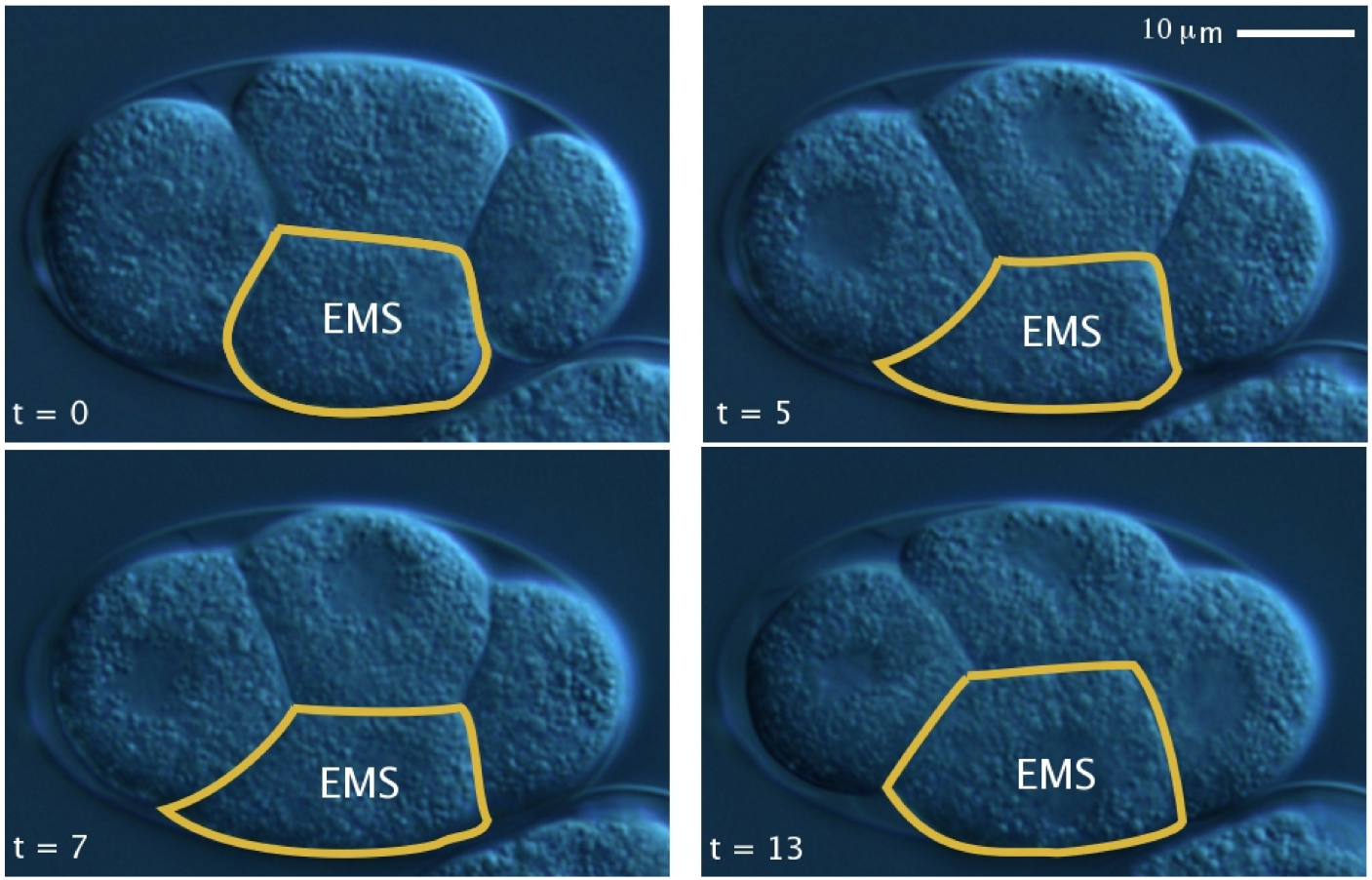
Why Quantify Biological Observations?

- Quantitative data supports assertions about qualitative observations.
- A model that reflects the biology accurately provides insight into the underlying forces.



Shape Changes Within the Four-Cell Stage



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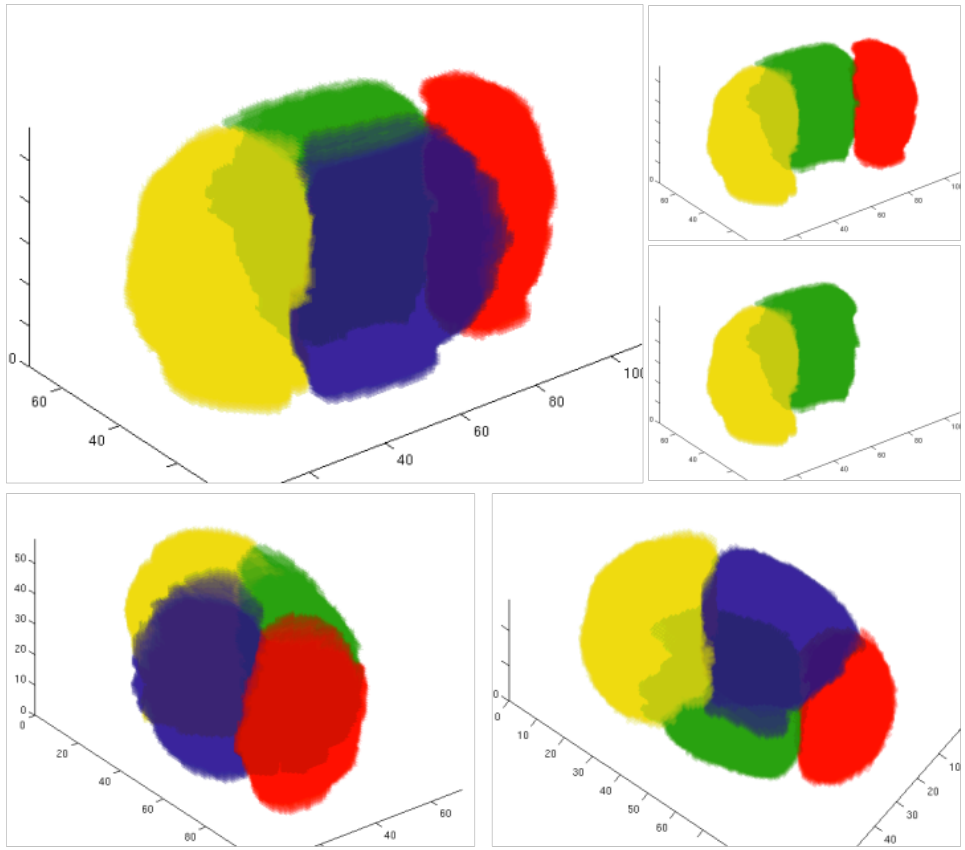
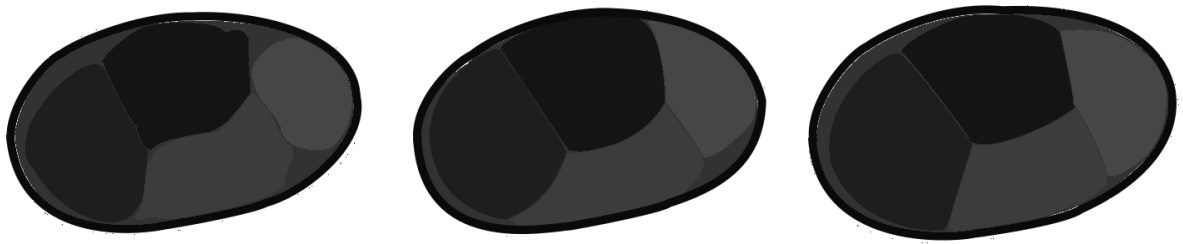
Summer 2007 Accomplishments

- Developed a functional Glazier-Graner-Hogeweg (GGH) model.
- Their model incorporates:
  - Target surface area & target volume
  - Cell-cell adhesion
  - Cell-eggshell adhesion
  - Centrosomal movement



Data Preprocessing & Input

- The model has been tested on a manually segmented four-dimensional data set.
- Images have been segmented by hand in The GNU Image Manipulation Program (GIMP) using the Bezièr curve tool.



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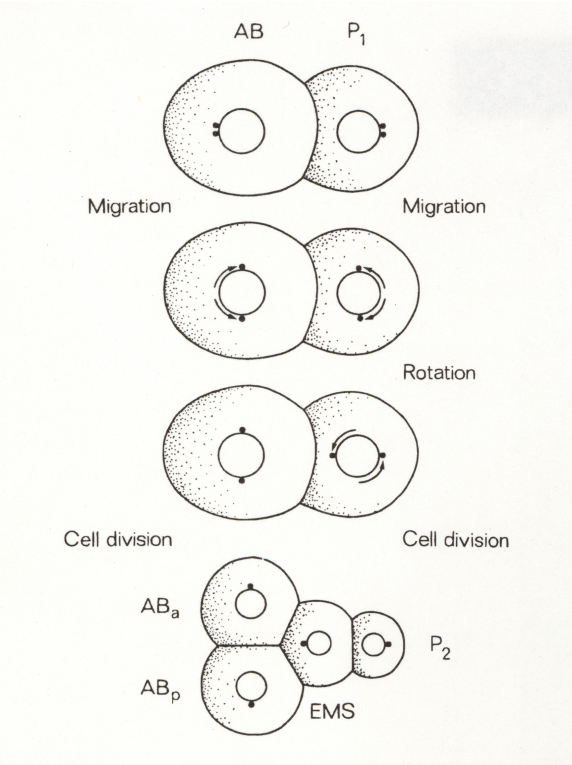
Automating Data Processing

- More data must be collected to validate the model.
- Manual segmentation can be:
  - Time consuming
  - Inconsistent
  - Inaccurate
- Differential interference contrast (DIC) imagery presents many segmentation difficulties.

Shell-less Embryo: Values for Target Volume and Surface Area



- The model requires relevant values for target volumes and surface area.
- Blastomere size is unconstrained by eggshell and can achieve its ideal volume and surface area.

[1] Diagram taken from B. Goldstein, S. N. Hird, and J. G. White. Development Supplement. 1993.

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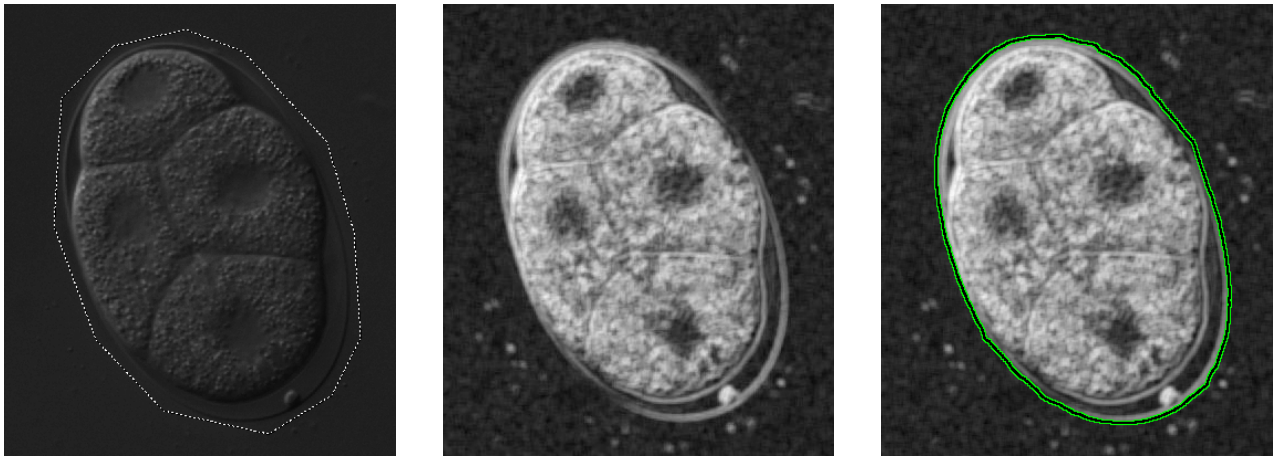
Region Based Active Contours



- The initial contour is represented as the zero level set of an implicit function.
- The curve is evolved to iteratively improve the segmentation until clearly defined regions are found.

[2]T.F. Chan and L.A. Vese, “Active contours without edges,"IEEE Trans. Image Processing, vol. 10, no. 2, pp. 266-277, Feb. 2001.

Watershed Transformation

- Consider an image as a topological surface: water is flooded from it's minima and watershed lines are built where the catchment basins would meet.

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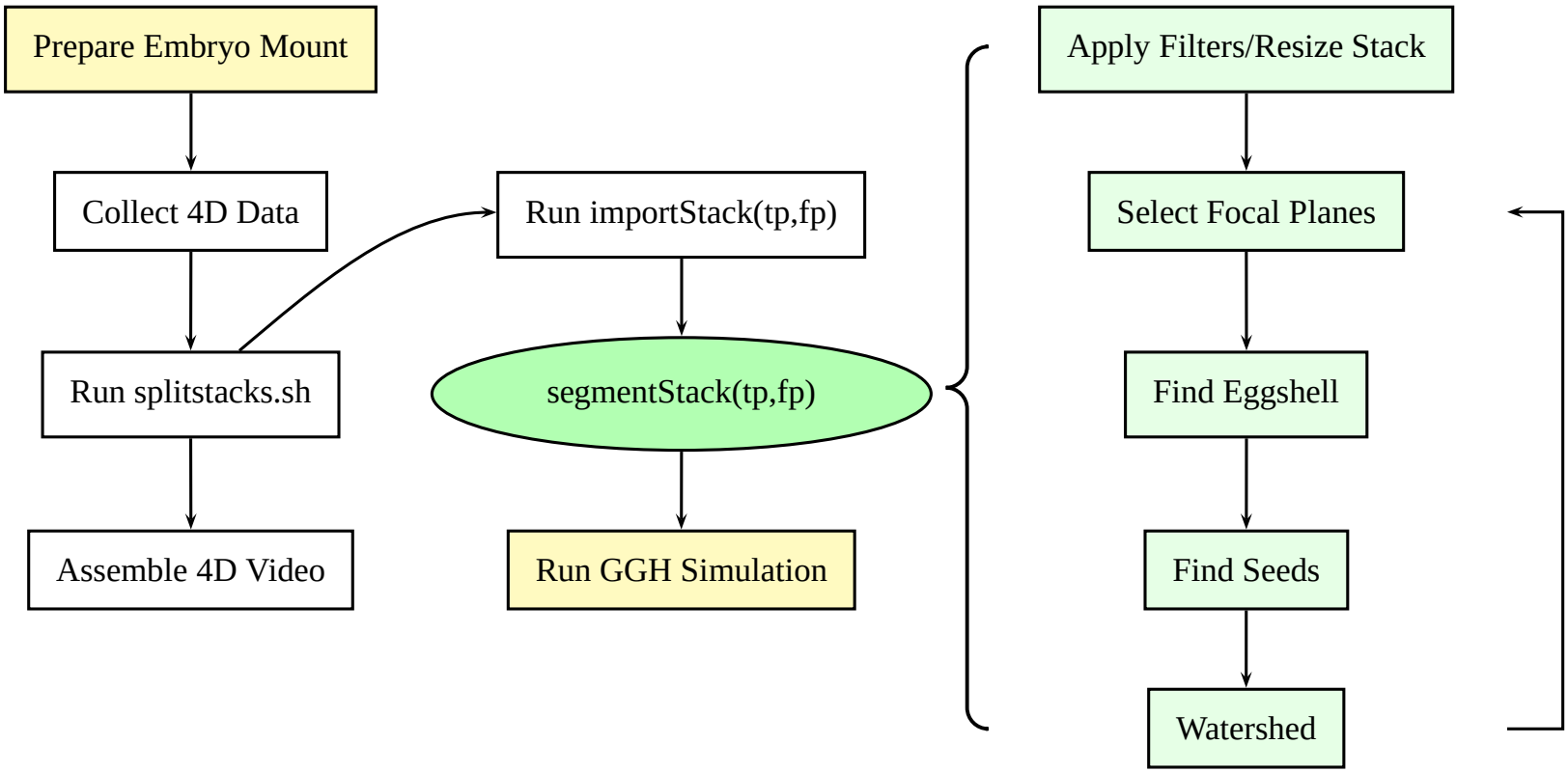
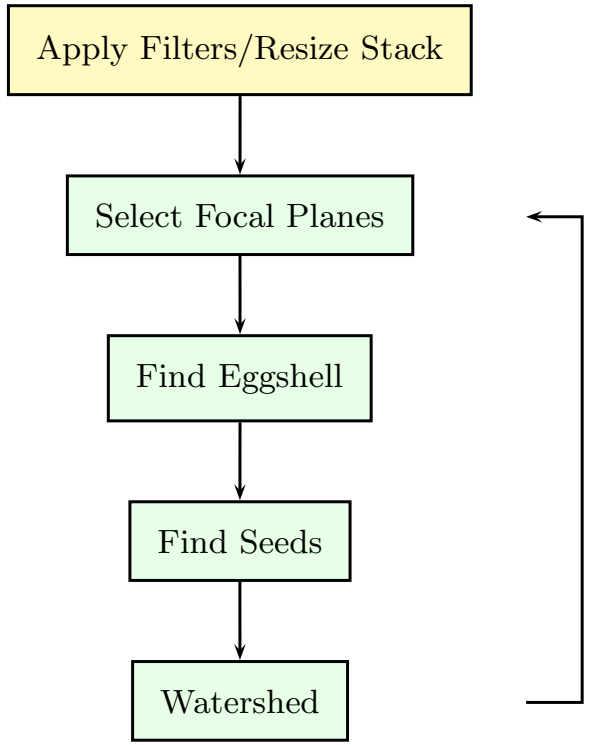
A Semi-Automated Scheme for Embryo Segmentation



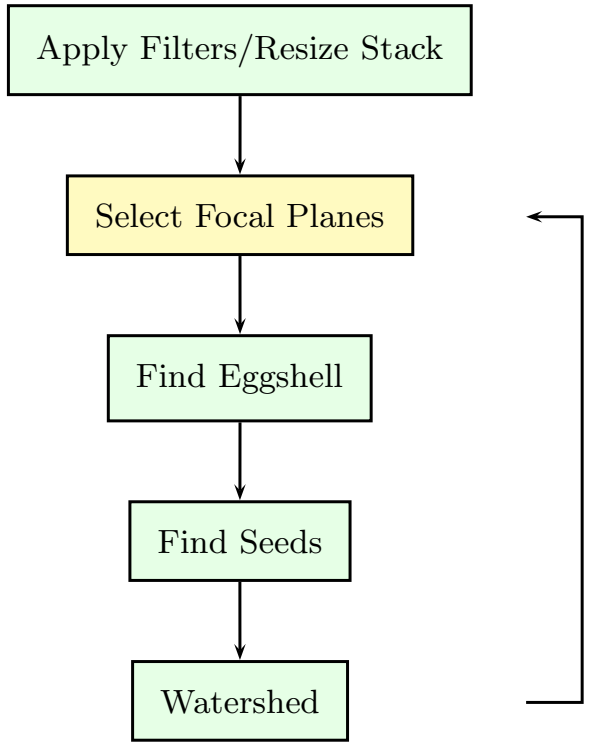
Running segmentStack(tp,fp)

- Standard deviation and entropy filters are used for finding eggshell and embryo outlines.



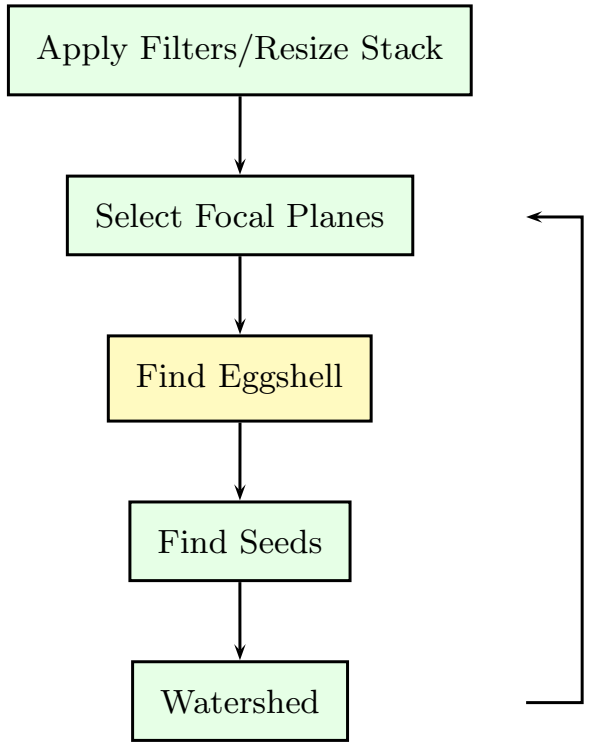
Running segmentStack(tp,fp)

- Select the focal planes in a given time point to manually seed.



Running segmentStack(tp,fp)

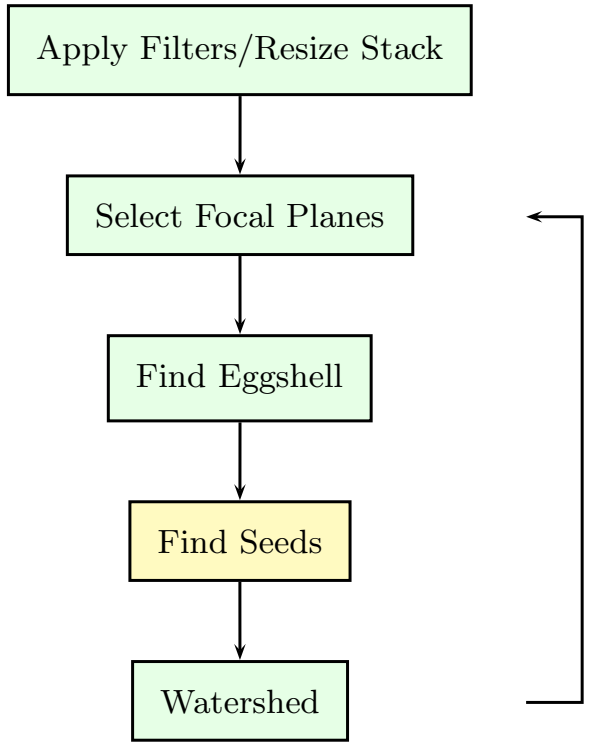
- Region-based active contours are used to find the eggshell & embryo outline.



[3] Active contour Matlab implementation is courtesy of Shawn Lankton.

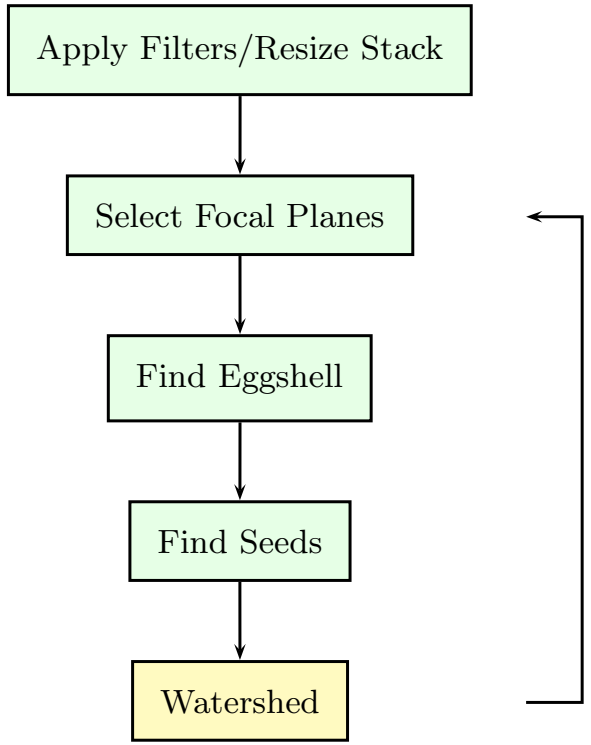
Running segmentStack(tp,fp)

- Draw regions in EMS, P2, ABa, and ABp on selected focal planes to seed.

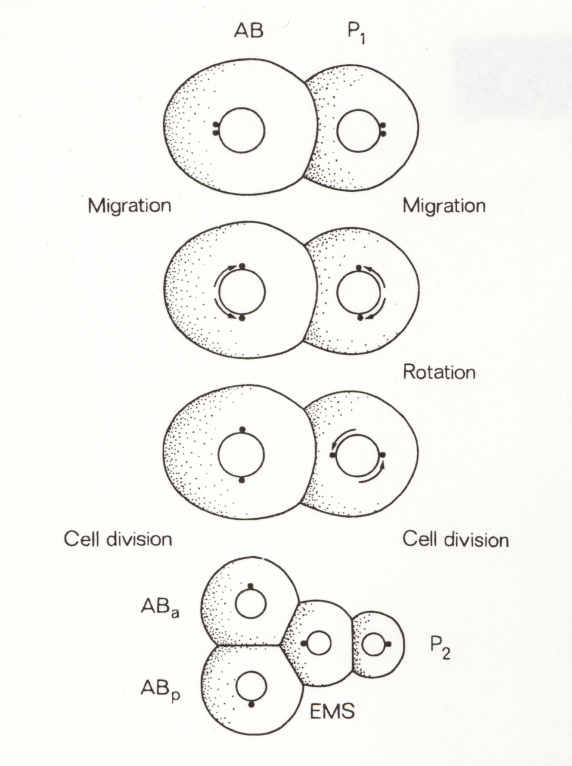


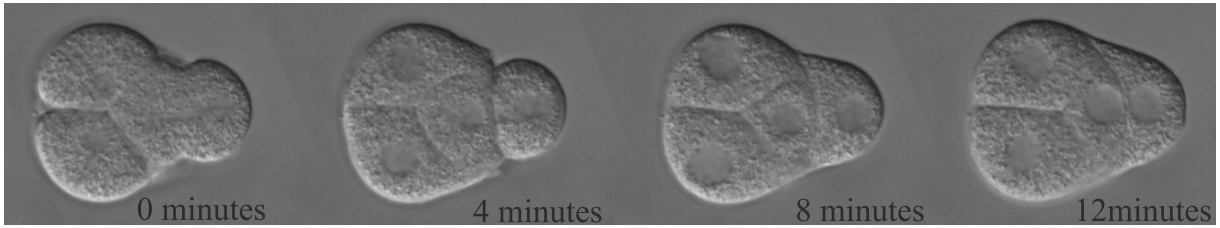
Running segmentStack(tp,fp)

- The seeds and gradient/threshold image are watershed resulting in a segmented four-cell embryo.



Unconstrained Data Set





- Unconstrained division orientations
- Unconstrained values for target volume and surface area of each cell

[4] Image taken from B. Goldstein, S. N. Hird, and J. G. White. Development Supplement. 1993.

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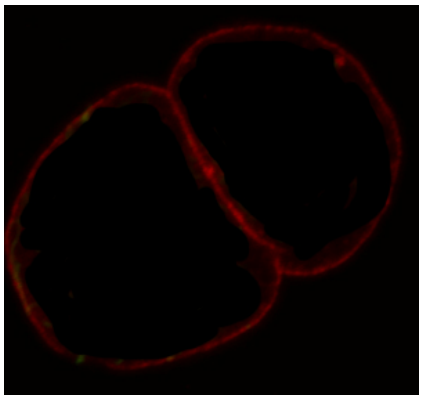
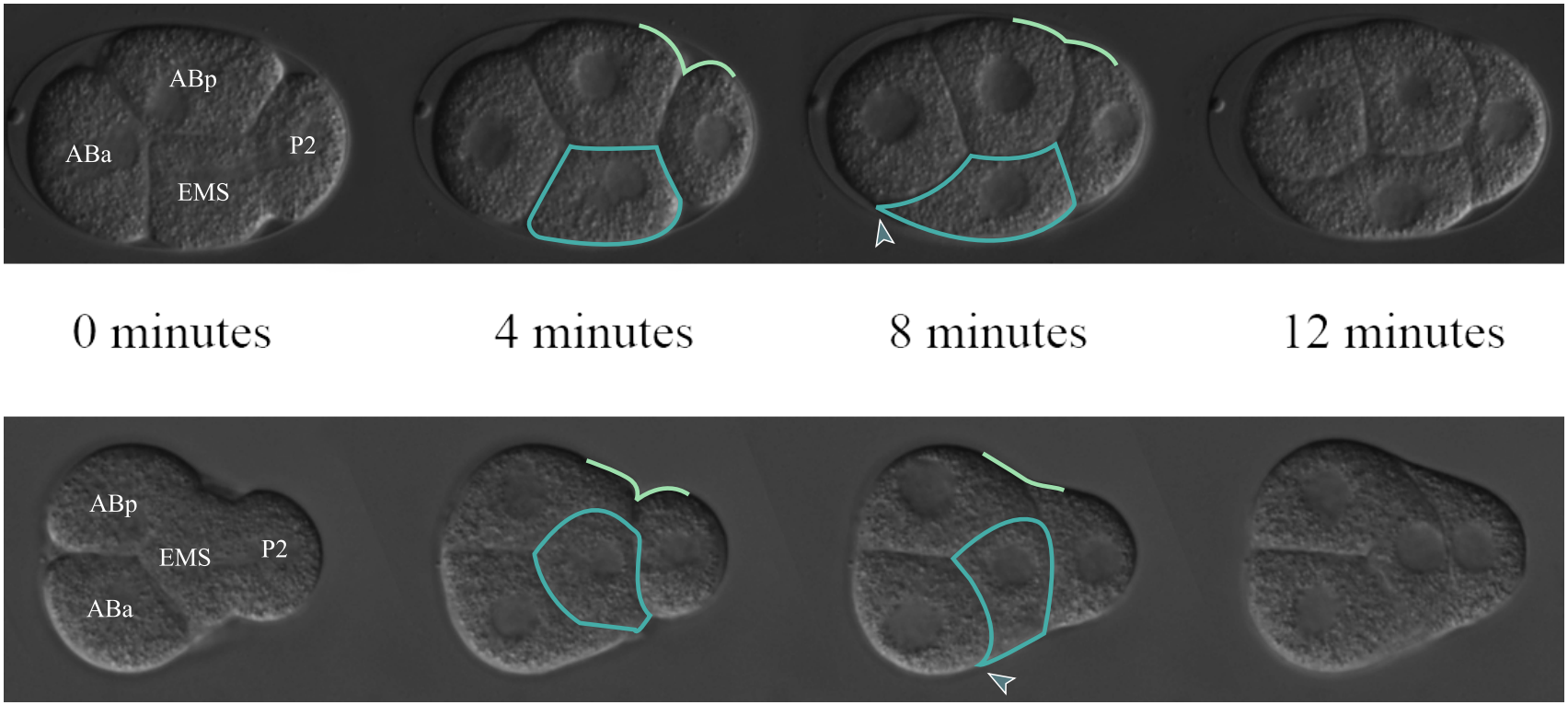
Future Directions: Segmentation



- Improve segmentation accuracy.
- Create a graphical user interface to improve ease of use.
- Potential for incorporating fluorescent imagery.
- Continue collecting data from:
  - Normal *C. elegans* for input into the GGH model.
  - Shell-less *C. elegans* embryos for comparison of surface area and volume to shelled embryos.

[5] Image courtesy of wormclassroom.org.

Future Directions: Biological Implications



Conclusion

Acknowledgements

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