Modeling Plant Life in Computer Graphics

Overview

Siggraph 2016 Course

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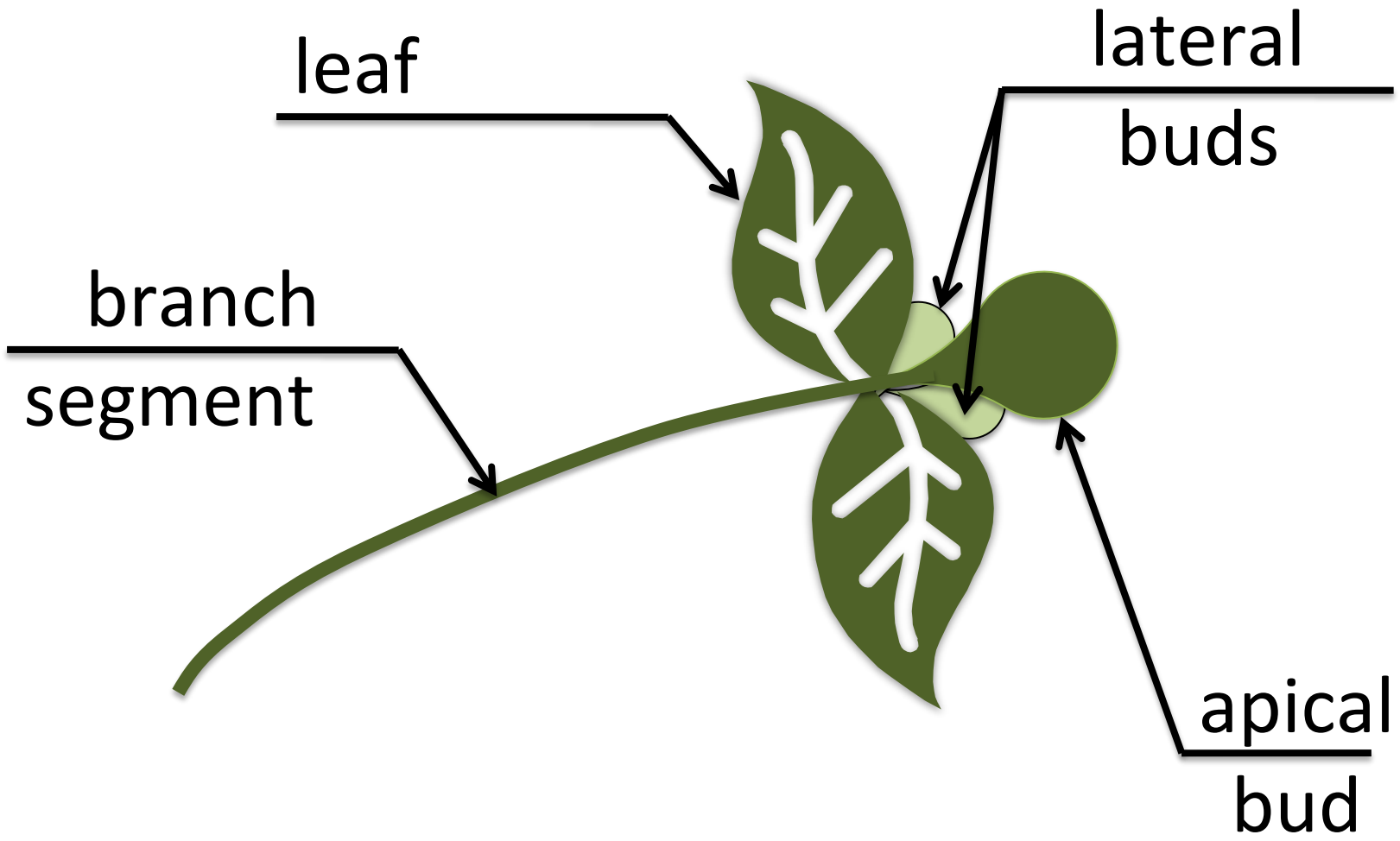
Plants in Computer Graphics

- Biologically-based simulations
- Plant is a modular system – basic elements (leaves, internodes, etc.)
- Ecosystems consider entire plant communities (a plant is a module)
- Plant geometry is the result of **interaction of the modules**

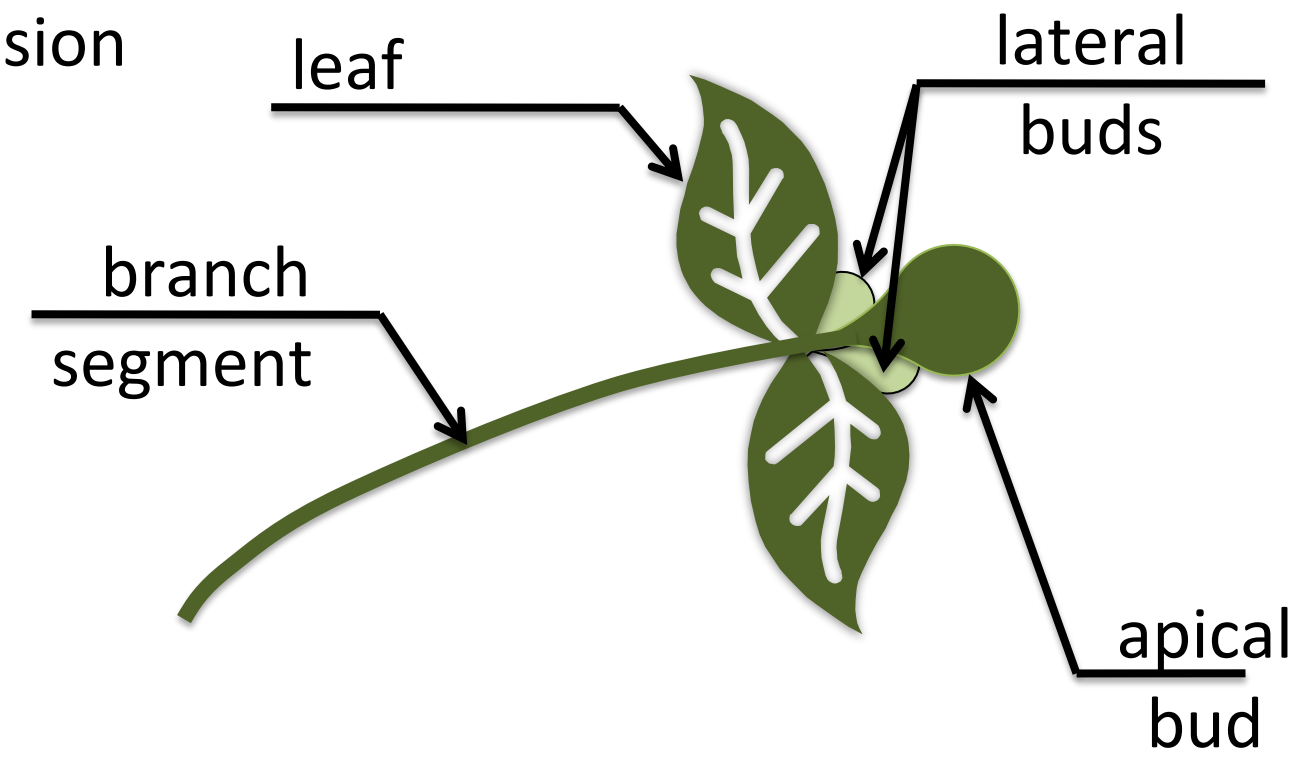
Plant Modules



Plant Growth

- Growth is biologically-based
- Uses plant modules to control the growth
- Primary growth – apex extension

- Apical bud
- Lateral buds
  - Initially dormant
  - Activated after some time



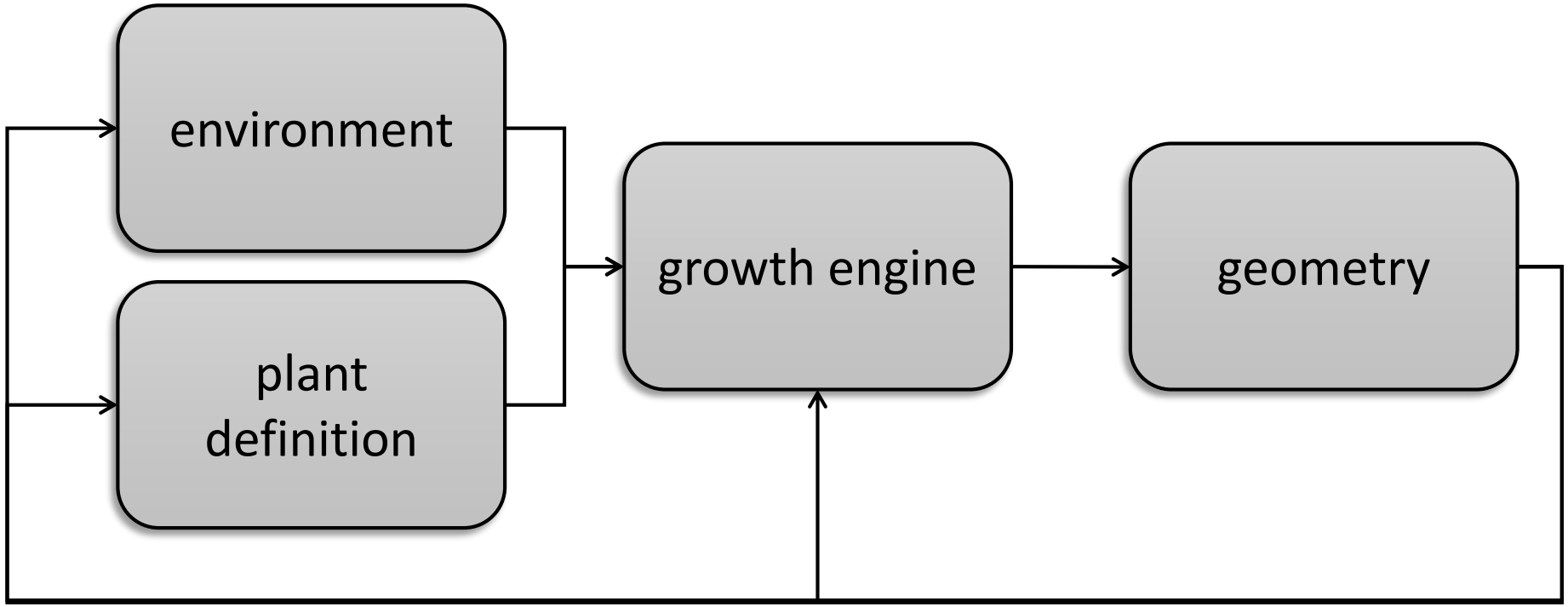
Plant Growth

- Secondary growth (cambial growth)

- Branch is getting thicker

- Annual rings formation

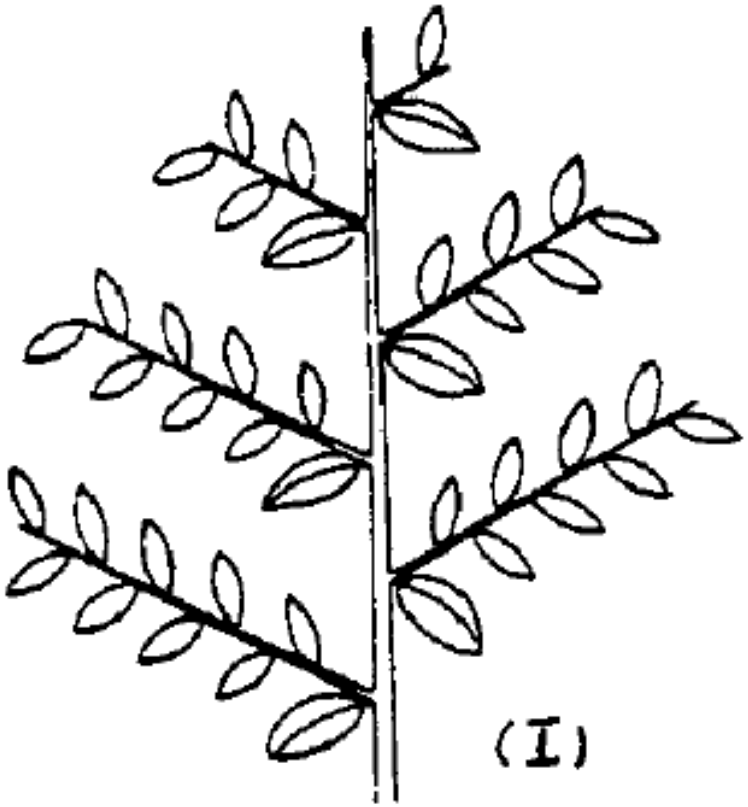
Generic Plant Modeling System



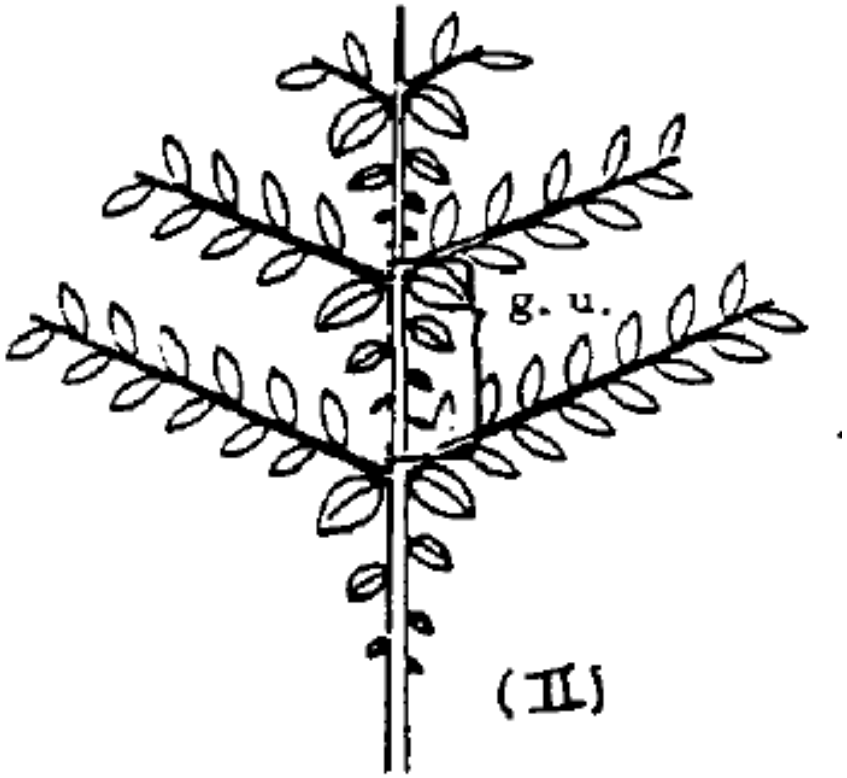
Plant Definition

- Ramification (branching)
- Biological model
- Bud lifespan
- Plant sensitivity to external impetus

Ramification



Continuous



Rhythmic

Image from (de Reffye et al 1988)

Axis (branch) order

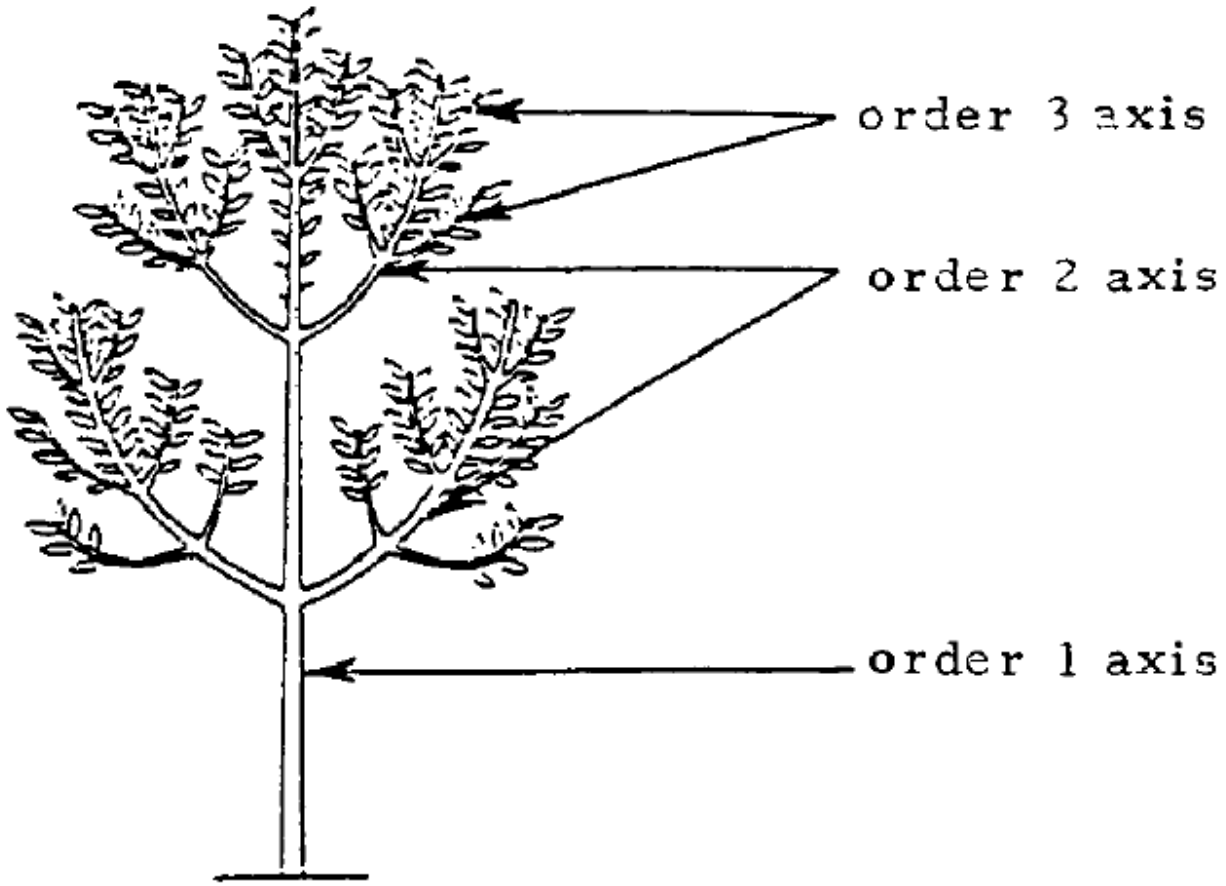
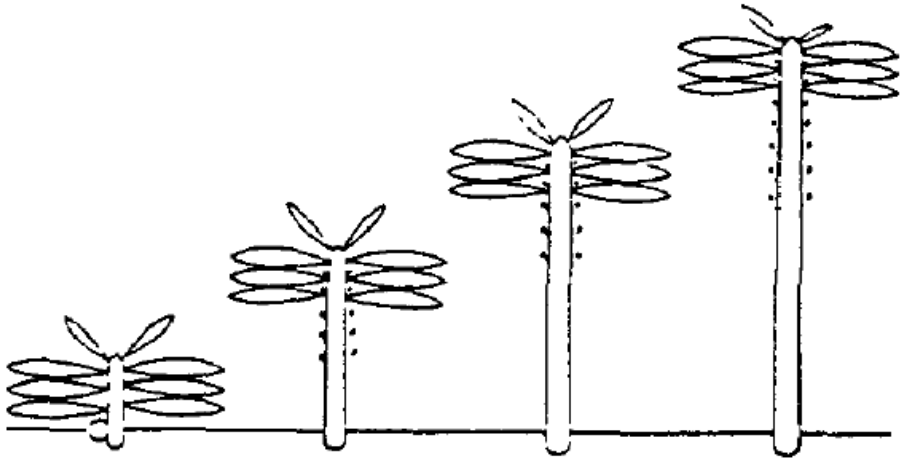
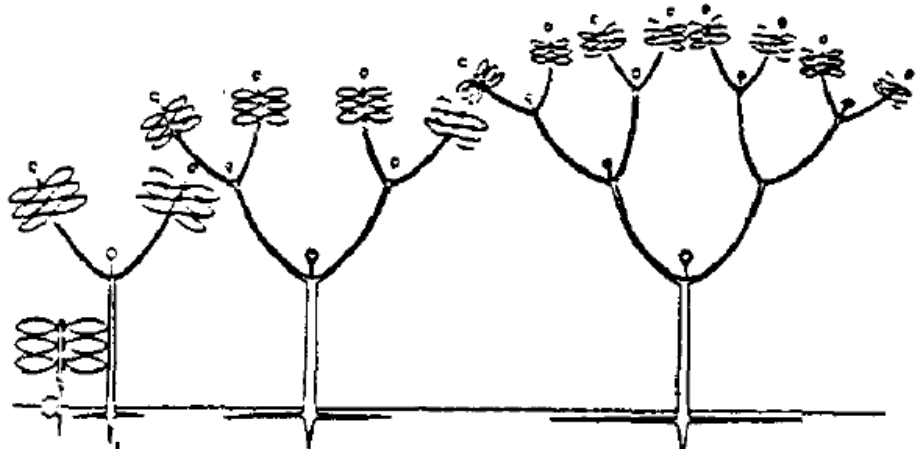


Image from (de Reffye et al 1988)

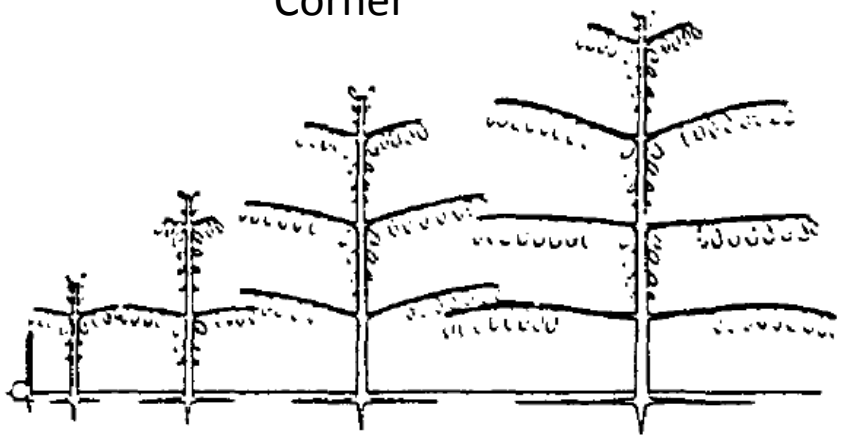
Biological Model



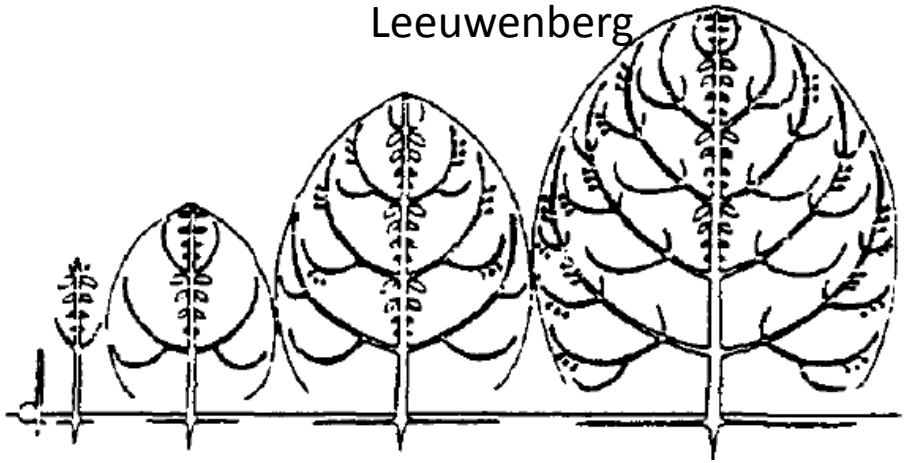
Corner



Leeuwenberg



Massart



Rauh

Images from (de Reffye et al 1988)

Light and Phototropism

- plant growth is driven by buds (“plant engines”)
- each bud evaluates its illumination
- determines the brightest spot (bending)
- % of illuminated buds on a branch determines its fate

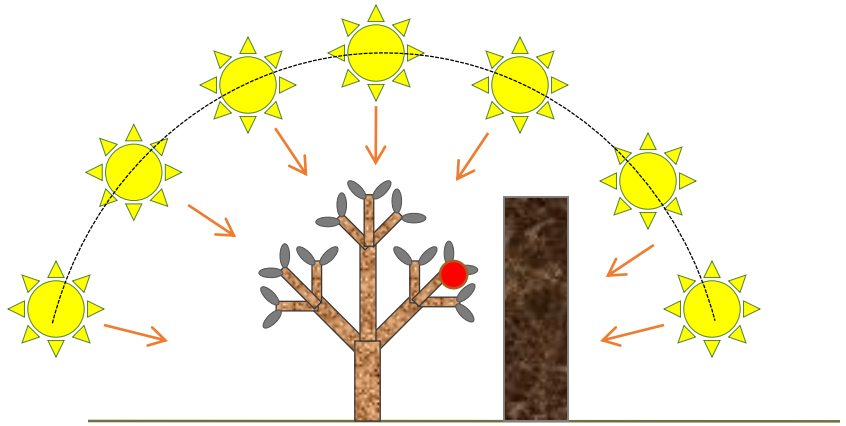
Illumination

- Phototropism
  - Branches tend to grow toward the light
  - Calculate the total illumination on a bud *i*

$$E_i = n_i / m$$

    - n_i – no. of positive samples
    - m – no. of all samples

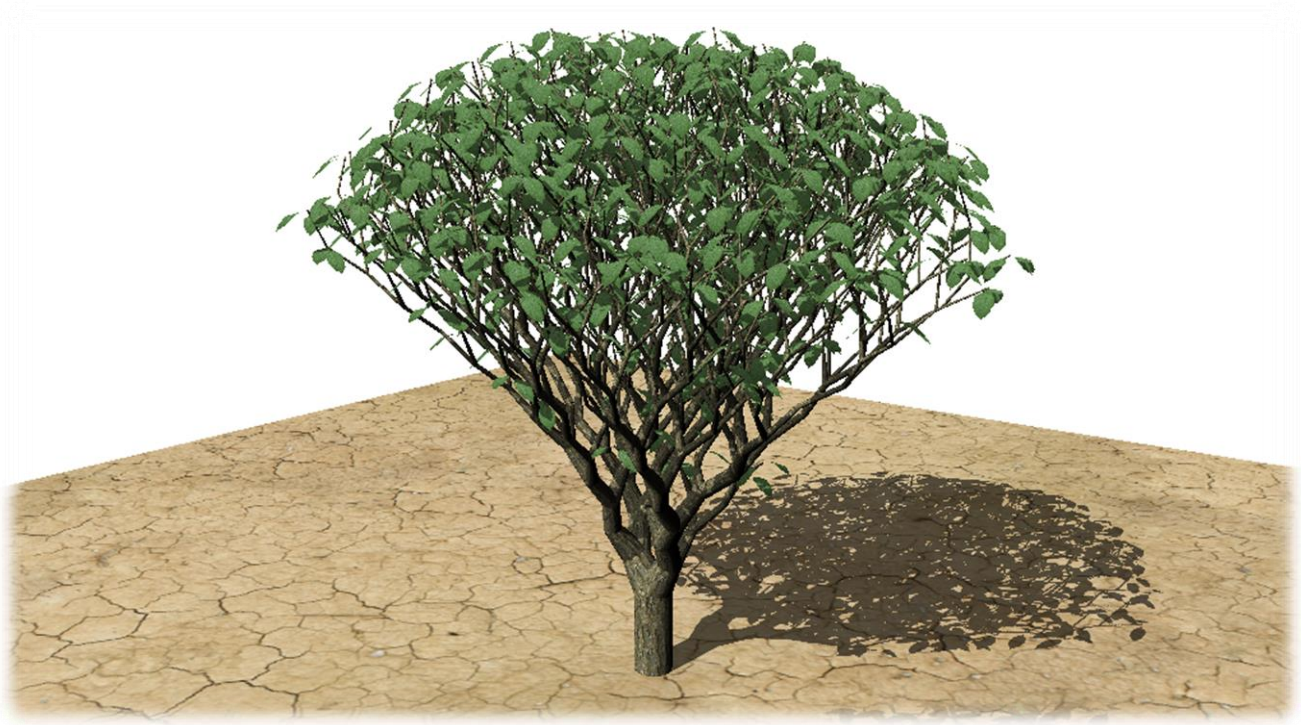
  - Find the brightest spot
    - Bend the direction



Light and Phototropism

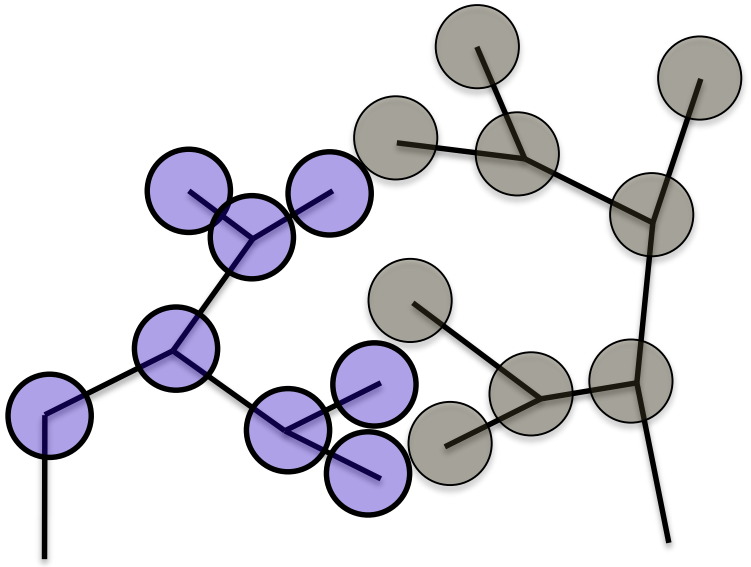
Gravity

- Gravitropism
  - Branches tend to grow against gravity



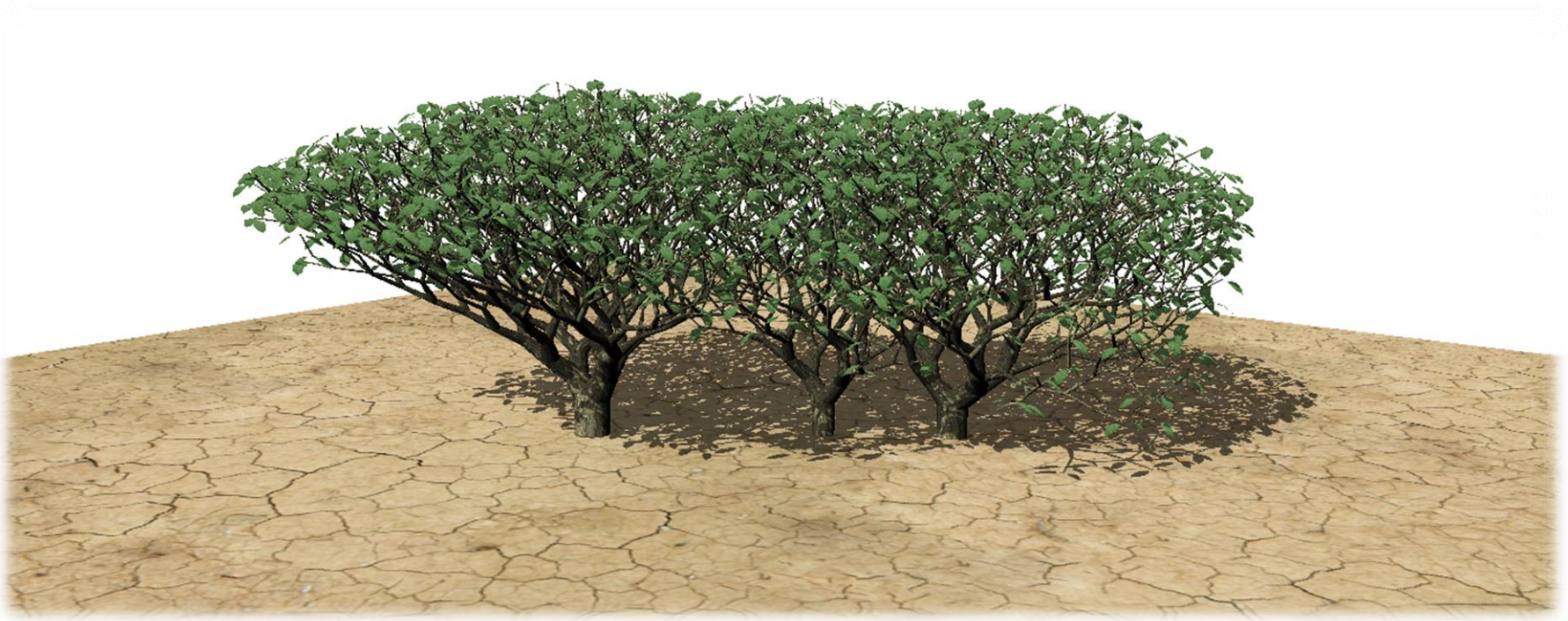
Competition for Resources

- Branches tend to avoid each other
- Honda model [Honda67]
  - A buds has a sphere of interest
  - Two spheres cannot overlap
  - If two spheres collide – do something



Competition for Resources

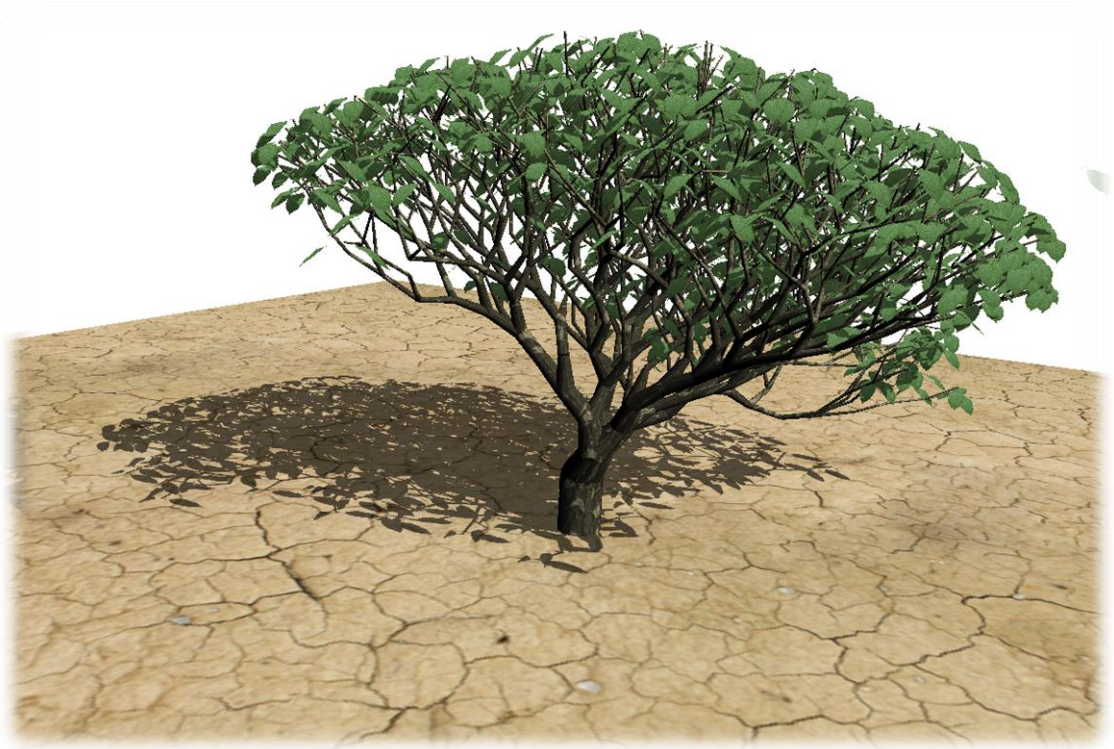
- a small ecosystem fighting for space on bud level



Competition for Resources

Competition for Space

- Branches compete for space



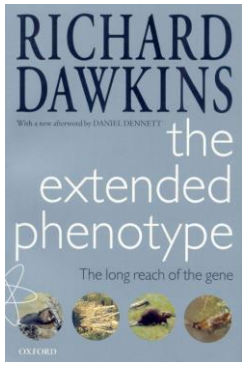
Competition for Resources

- at the level of an ecosystem

image from
Palubicki, W., Horel, K., Longay, S., Runions, A., Lane, B., Měch, R., and Prusinkiewicz, P., (2009) Self-organizing tree models for image synthesis. ACM Trans. Graph. 28, 3, Article 58 (July 2009), 10 pages.

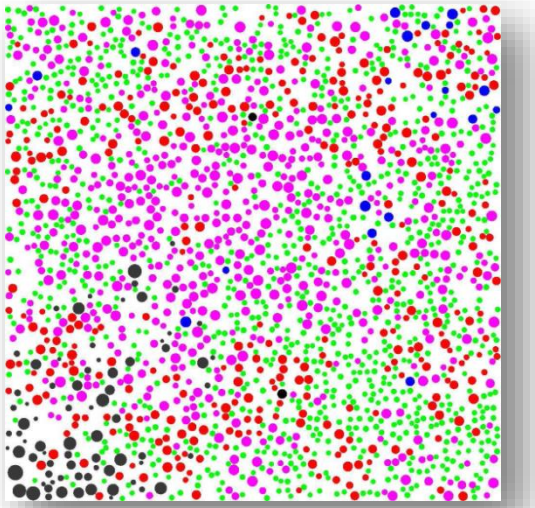
Ecosystems

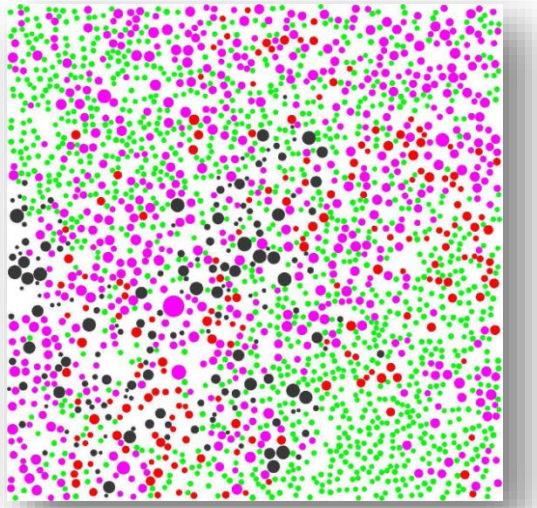
- A module, so far, was a part of a plant
- An entire plant can be thought of as a module
- Plants compete for resources (Extended Phenotype – Dawkins)
- Result of the competition are ecosystems



Ecosystems

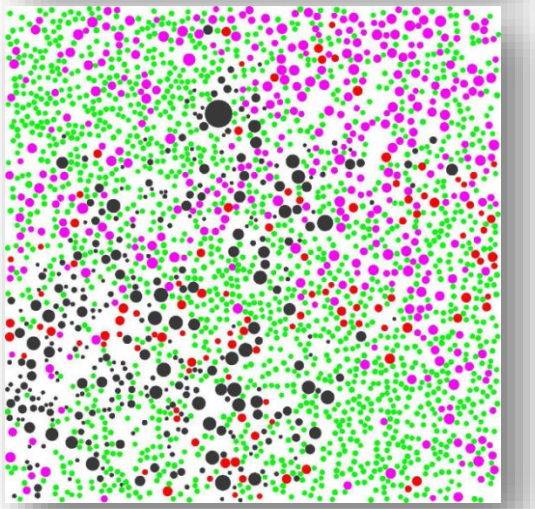
25 years

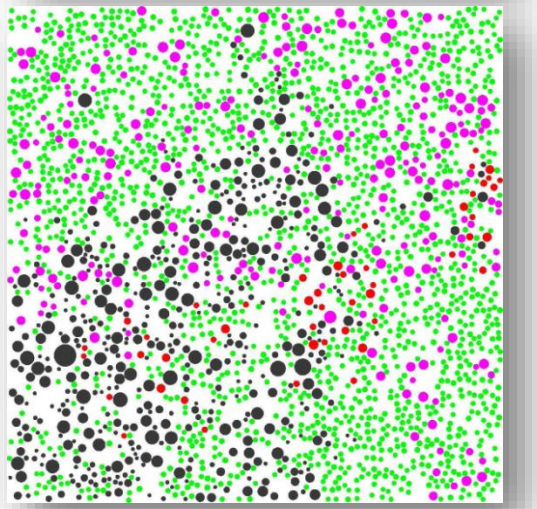




75 years

100 years





125 years

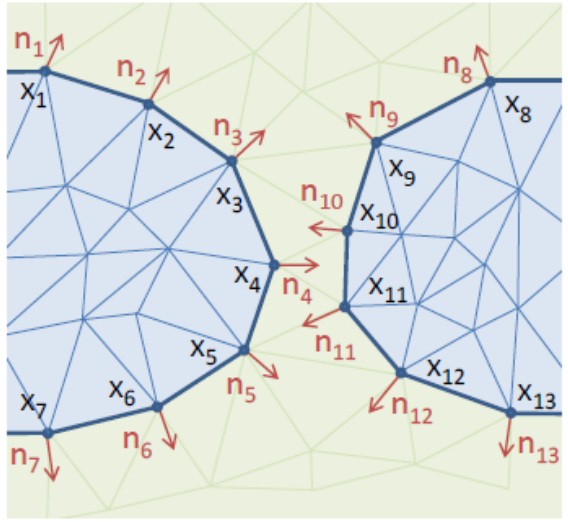
Urban Ecosystems

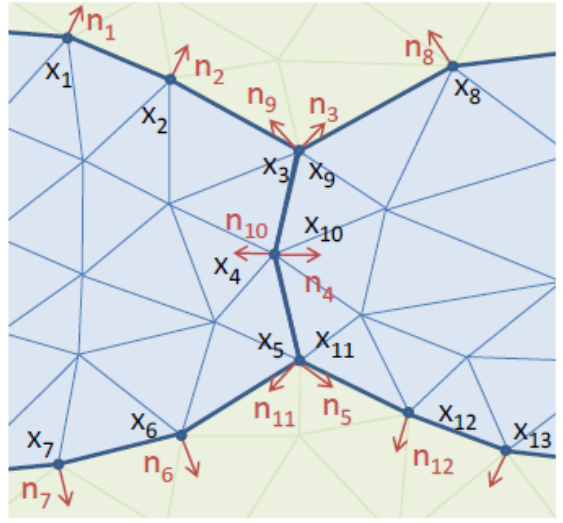
Cambial (Secondary) Growth

Kratt, J., Spicker, M., Guayaquil, A., Fiser, M., Pirk, S., Deussen, O., Hart, J.C., and Benes, B., (2015) Woodification: User-Controlled Cambial Growth Modeling in Computer Graphics Forum (Proceedings of Eurographics 2015), 33 (2), 361-372 (DOI=10.1111/cgf.12566)

Cambial (Secondary) Growth

- Uses deformable simplicial complexes
- Propagate vertices based on growth function
- Detection of collisions and self-intersections
- Adds cracks





Cambial (Secondary) Growth

Used References

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- Palubicki, W., Horel, K., Longay, S., Runions, A., Lane, B., Měch, R., and Prusinkiewicz, P., (2009) *Self-organizing tree models for image synthesis*. ACM Trans. Graph. 28, 3, Article 58 (July 2009), 10 pages.
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