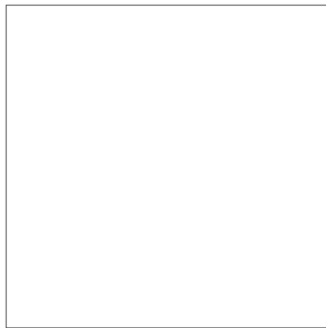# Computer Graphics

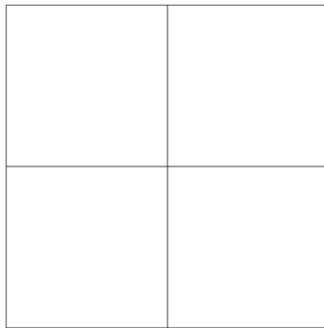## *Procedural Methods - L-Systems Part 2*

Mark Pauly

Geometric Computing Laboratory

Inverse Problem: Regular Grid
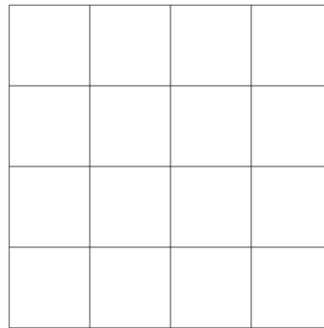
- Which L-System creates this output?
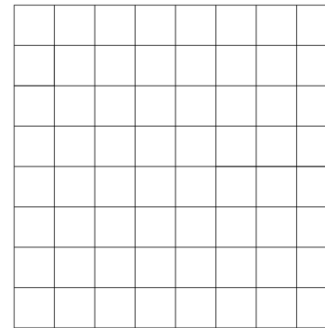 - define the axiom and the rule(s)

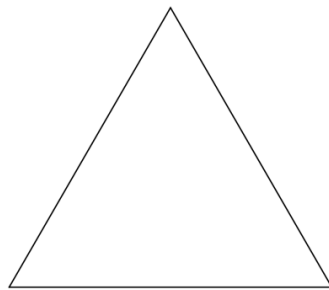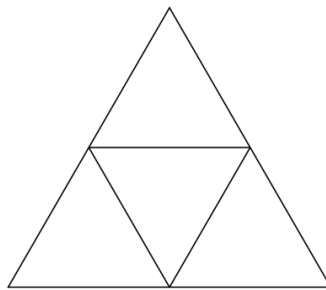| *level 0 = axiom* | *level 1* | *level 2* | *level 3* |

- Solution
  - Axiom: $F + F + F + F + F$
  - Rule: $F \rightarrow F + F - -F + F$
  - Angle: 90

2

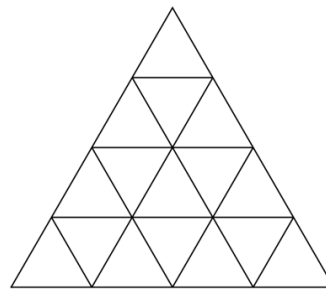# Inverse Problem: Regular Grid

- Which L-System creates this output?
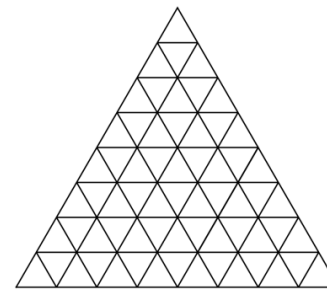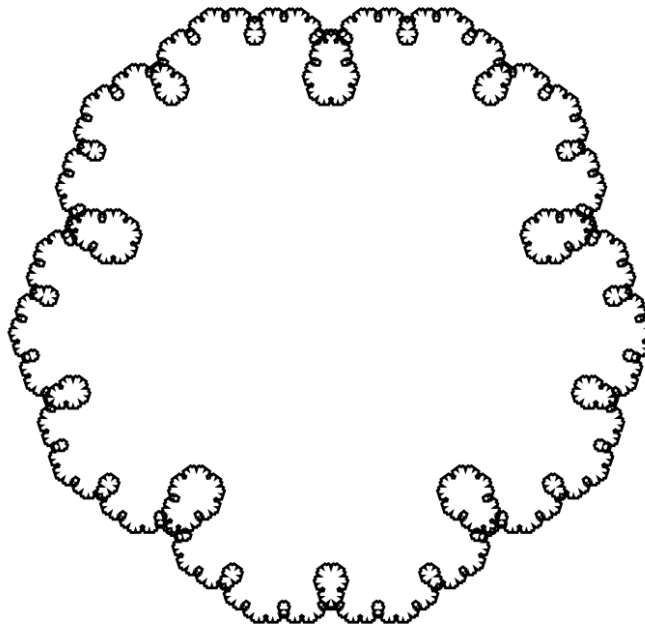 - define the axiom and the rule(s)

level 0 = axiom   *level 1*   *level 2*   *level 3*

- Solution
  - Axiom: $F++F++F$
  - Rule: $F \rightarrow F++F---F+F$
  - Angle: 60
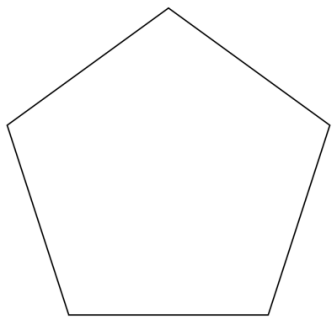
Inverse Problem: Penta Flower

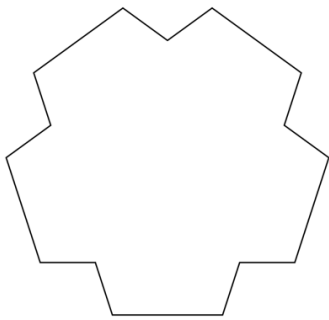- Which L-System creates this output?
  - define the axiom and the rule(s)
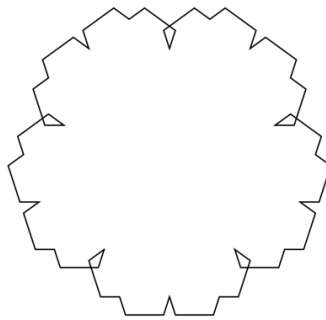
What??

Inverse Problem: Penta Flower

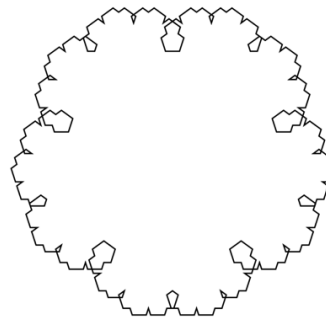- Which L-System creates this output?
    - define the axiom and the rule(s)

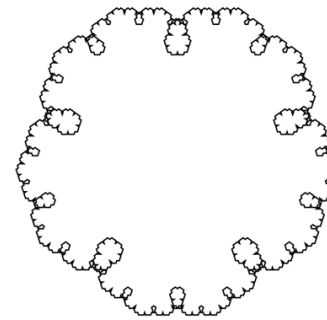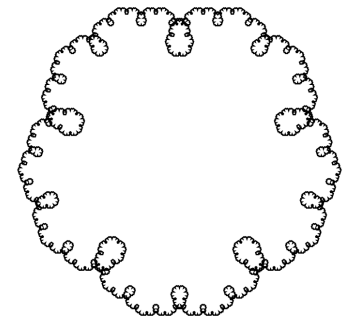

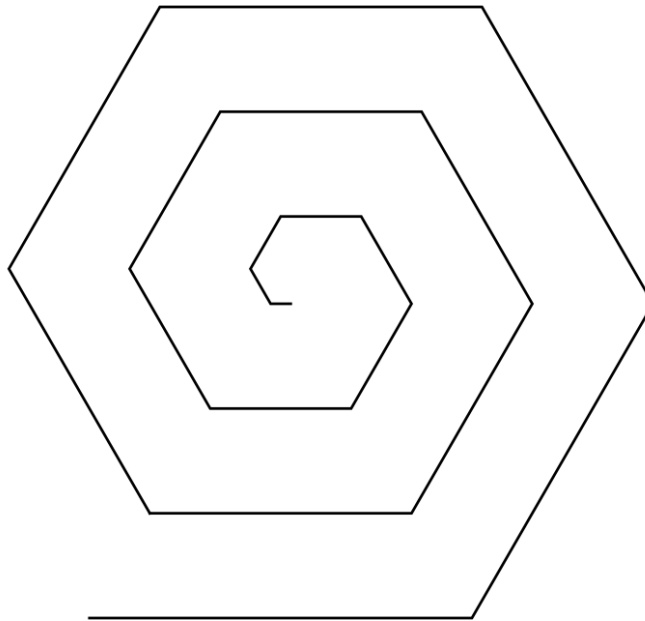| level 0 | level 1 | level 2 | level 3 | level 4 | level 5 |

- Solution
    - Axiom: $F + F + F + F + F$
    - Rule: $F \rightarrow -F + FF + F-$
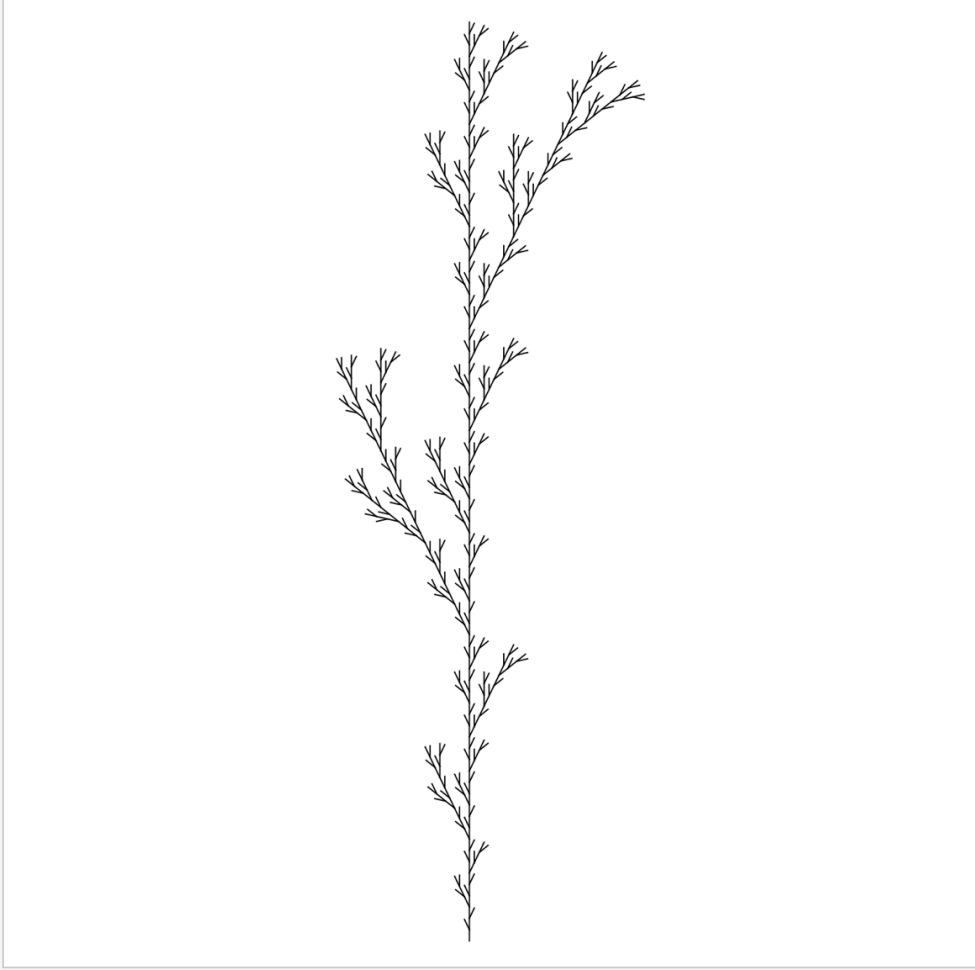   - Angle 72

Inverse Problem: Spiral

- Which L-System creates this output?
  - define the axiom and the rule(s)

Branching Structure

- Branching is prevalent in plants

- Bracketed L-Systems introduce two new symbols: [and] to push and pop turtle's state

- Example: $F[+F][-F[-F]F]F[+F][-F]$

Examples
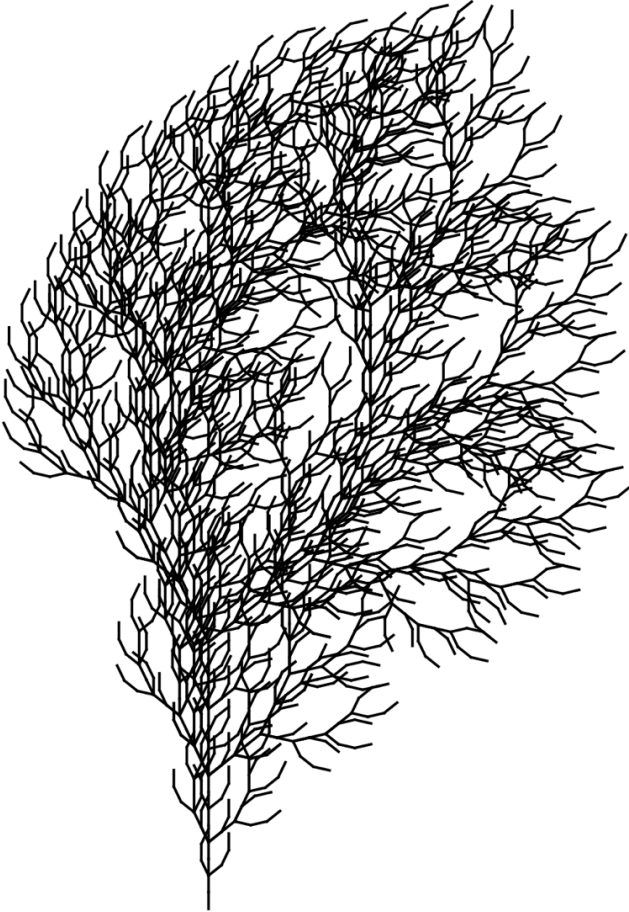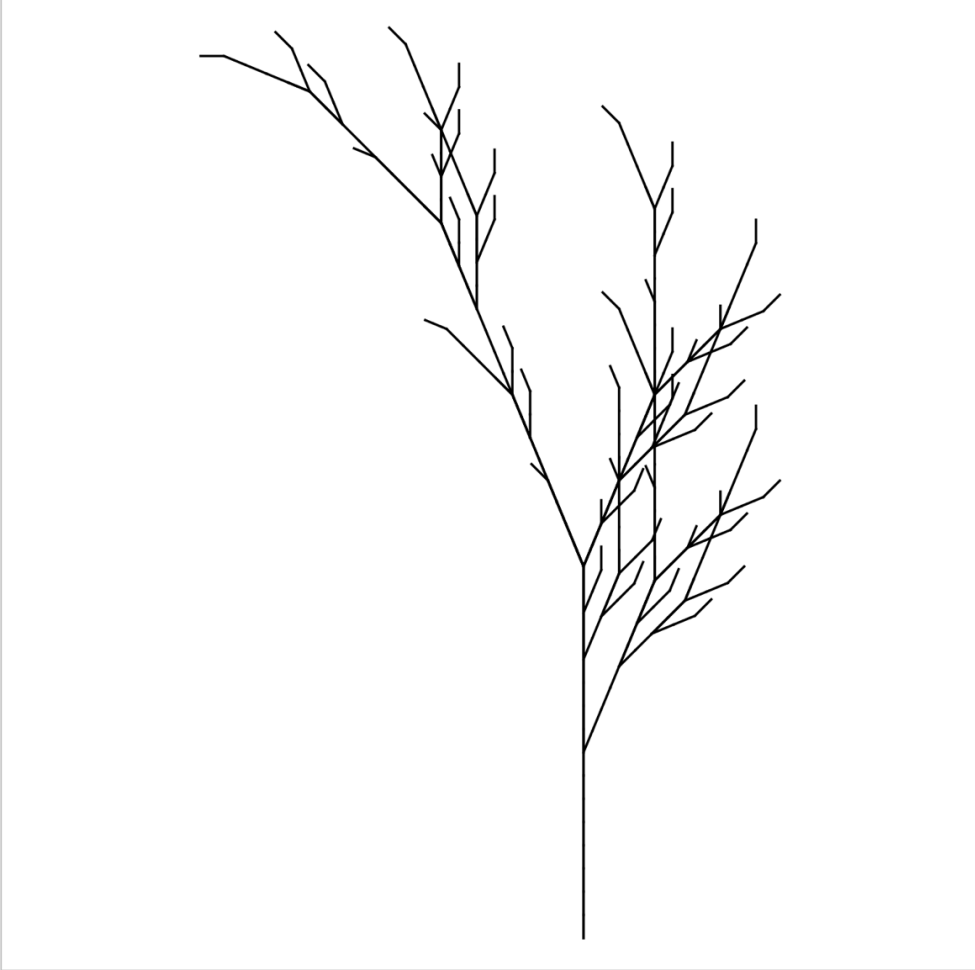
Examples

Examples

Inverse Problem: Tree

- Which L-System creates this output at level 5 for angle 20?
    - define the axiom and the rule(s)

- Solution
    - Axiom: F
    - Rule: $F \rightarrow F[+F][-F]$

Inverse Problem: Tree

- Which L-System creates this output at level 5 for angles 60, 90, 120, resp.?
  - define the axiom and the rule(s)

Stochastic L-Systems
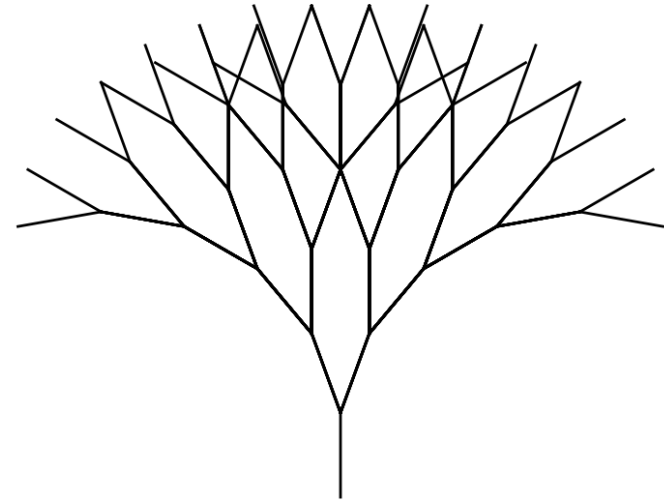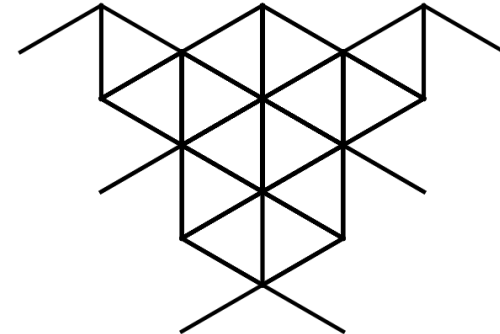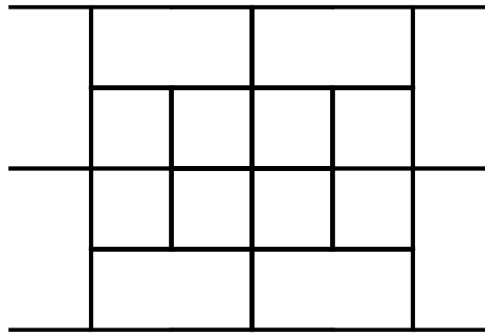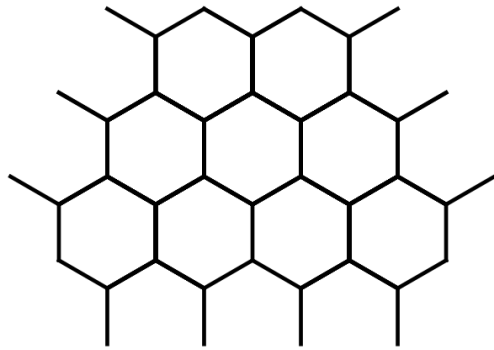
- **Problem**: All plants generated by the same deterministic L-System are identical.
    - We want specimen-to-specimen variations that will preserve the general aspects of a plant but will modify its details.

- **Solution**: Stochastic L-Systems provide a probability for each production rule. Production rules are chosen according to this probability distribution
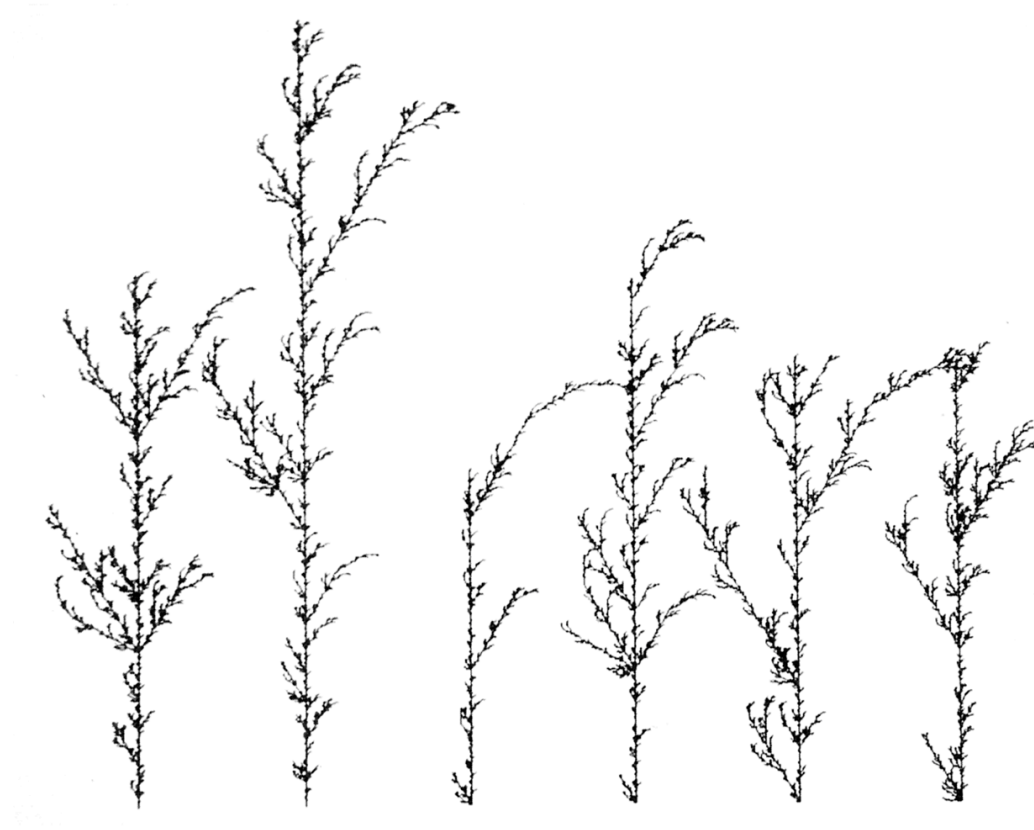
$$\omega : F \tag{1}$$

$$p_1 : F \xrightarrow{.33} F[F+F]F[-F]F \tag{2}$$
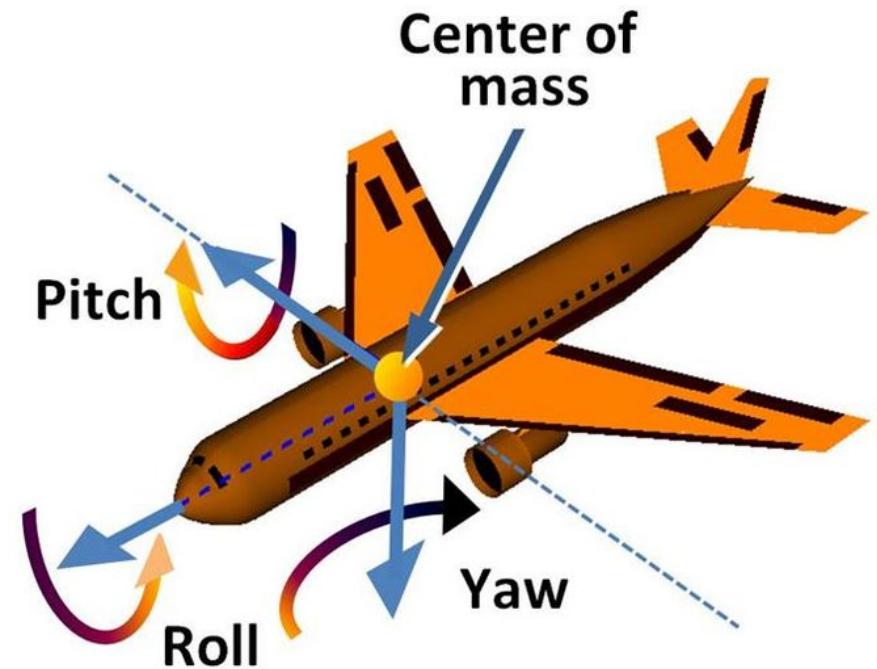
$$p_2 : F \xrightarrow{.33} F[F+F]F \tag{3}$$

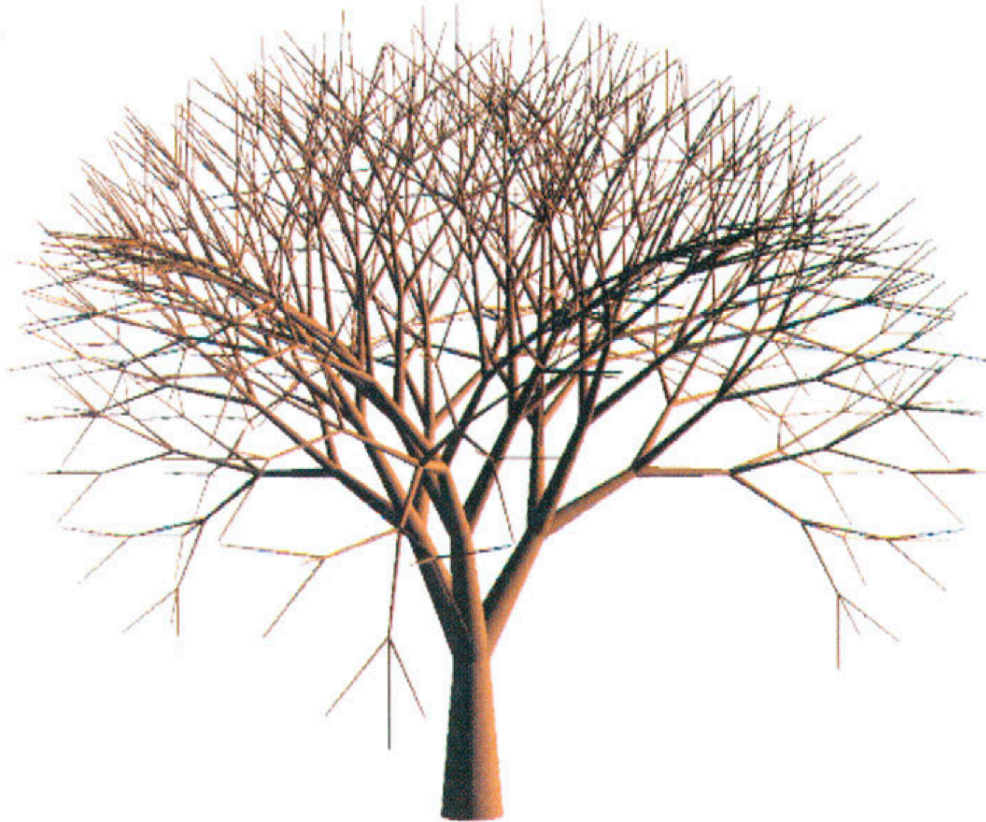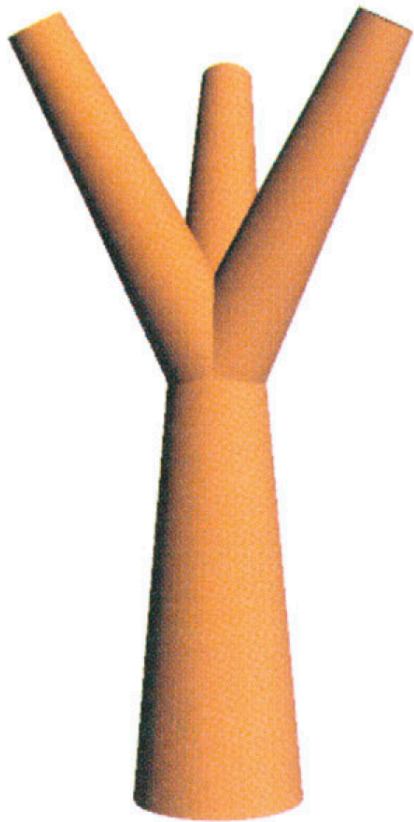$$p_3 : F \xrightarrow{.34} F[-F]F \tag{4}$$
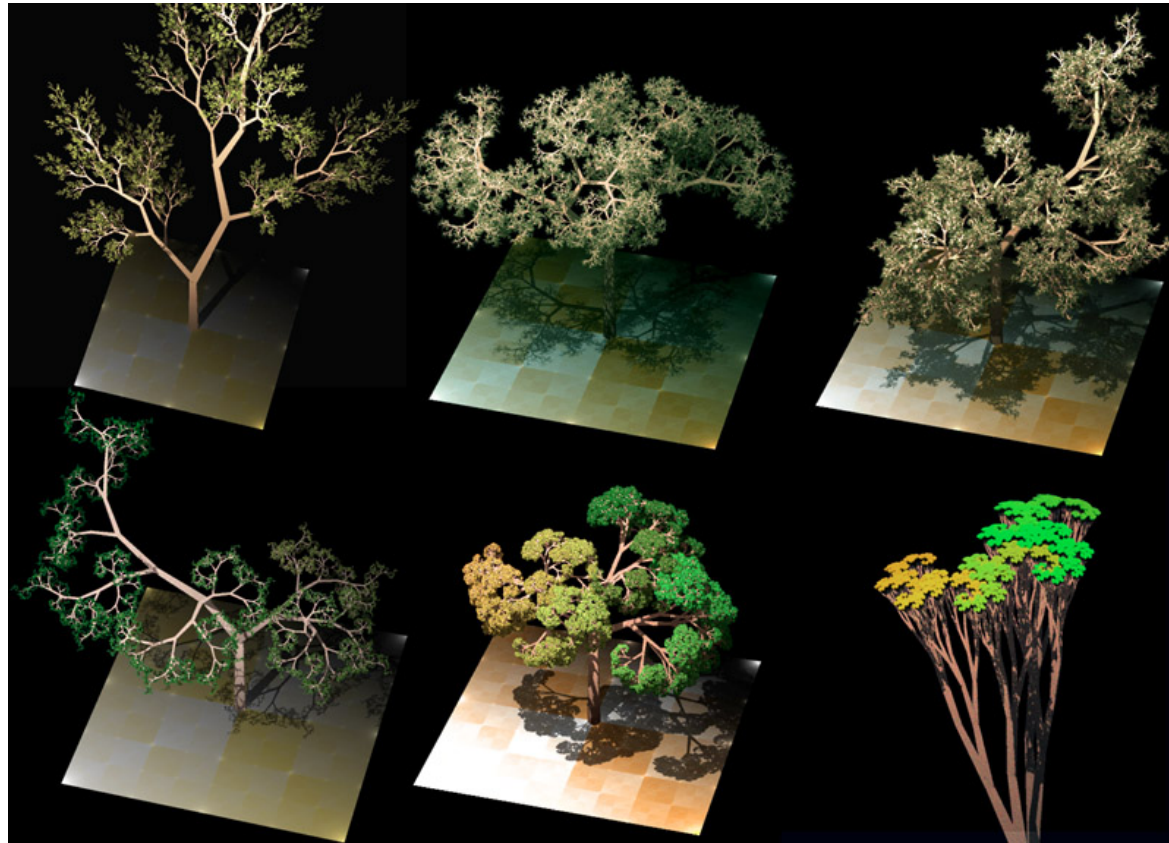
Stochastic L-Systems

3D L-Systems

- Position is now $(x, y, z, \alpha, \beta, \gamma)$.
- ^: Pitch up by angle δ
- &: Pitch down by angle δ
- /: Roll right by angle δ
- \: Roll roll left by angle δ
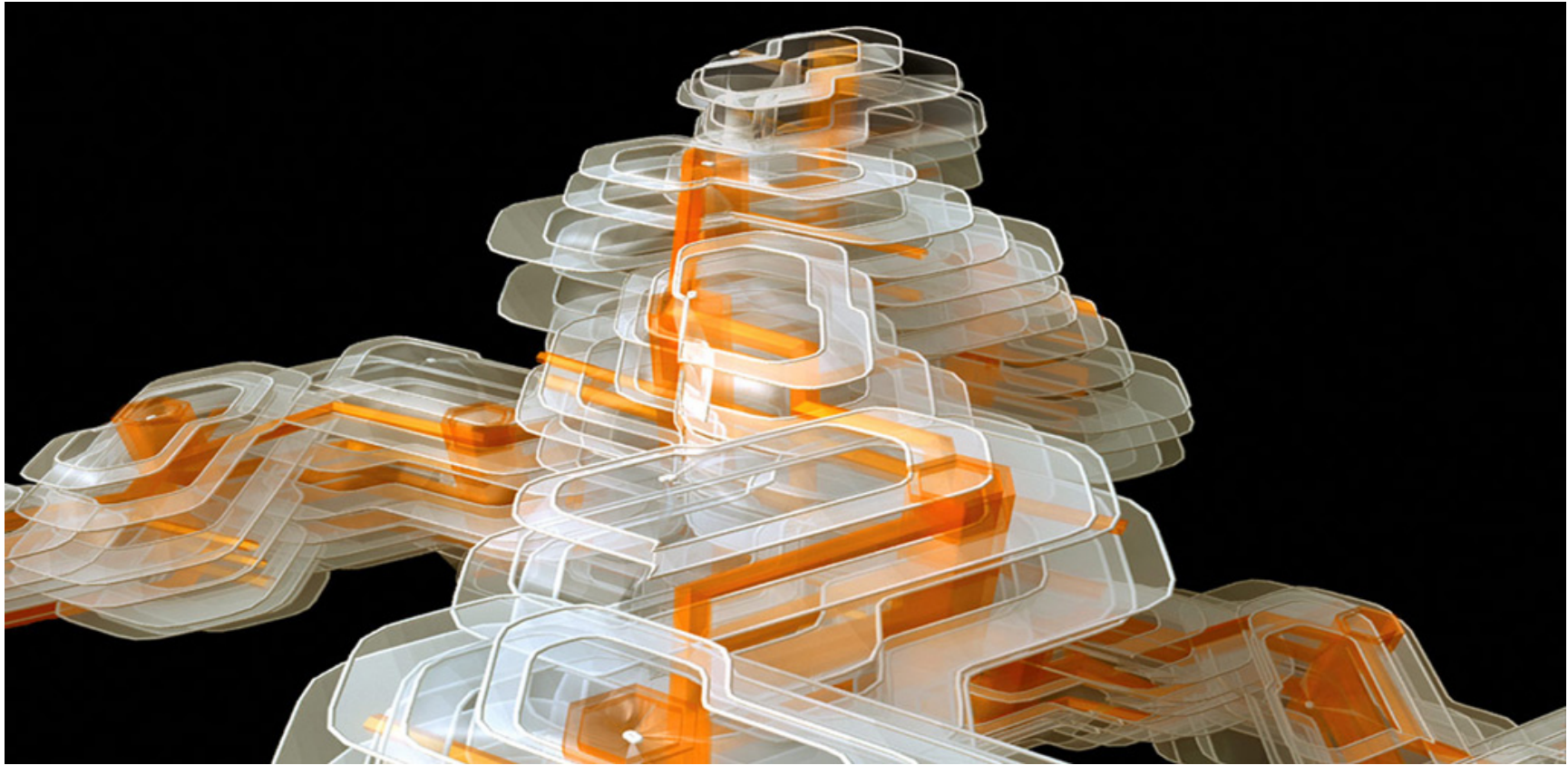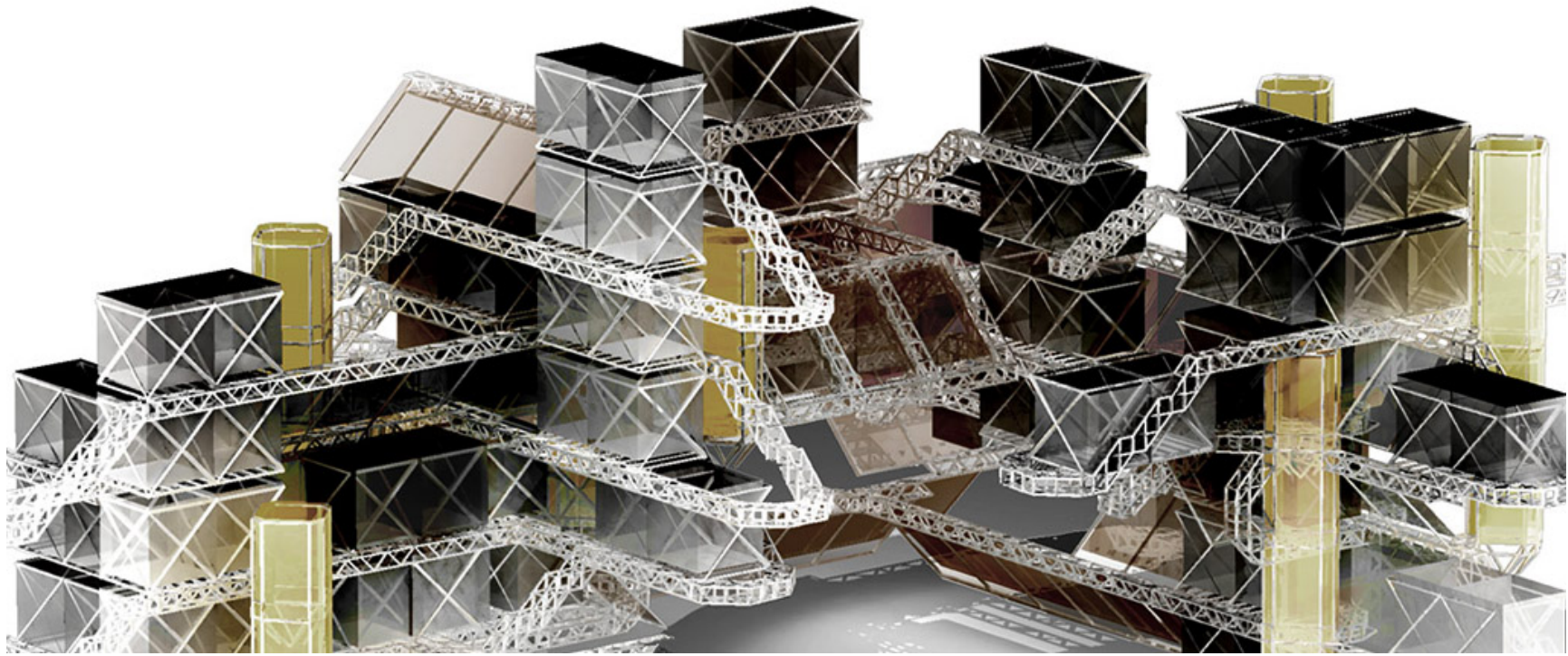- |: Turn around

3D L-Systems

3D Stochastic L-Systems

L-Systems in Architecture

L-Systems in Architecture

Other Extensions

- Context-sensitive L-Systems

- Accessibility of light/competing for light

- Influence of gravity

- etc.

Literature