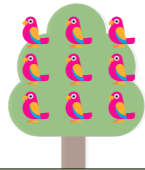## Slide 1

✨ **No Laptop Monday Funday!** ✨

# Week09

– directed graph preview
– trees

**BOTANY WARMUP**
what is a tree?
what is a branch?
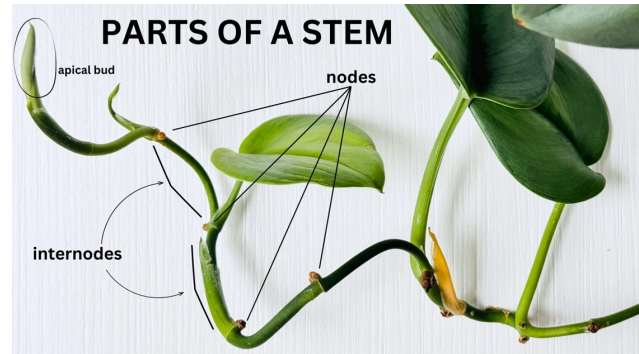what is a node?

**ADDITIONAL WARMUP**
what does binary mean?
what is a binary tree?
what does ternary mean?

[record lecture]

1

## Slide 2

**PARTS OF A STEM**

apical bud

nodes

internodes

2

## Slide 3

# directed graphs

3

## Slide 4

**quick note:** Math vs. CS

4

## Slide 5

### CS vs. Math

– a **directed graph** is a data structure
  – it has **nodes** that **refer** to any number of other nodes

– a **directed graph** G = (V, E) is also a mathematical object
  – it has **vertices** (**nodes**) V
  – it has **directed edges** E
    – **note:** E is a set of 2-tuples

5

## Slide 6

these are really just two different ways
of looking at the same thing

6

## both are useful!
(Math to figure out the algorithm, CS to code it up)

## in CSCI 136, i will focus on the CS view
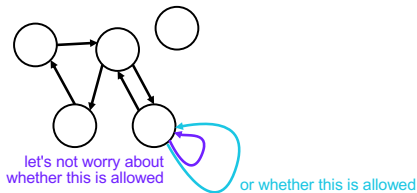(MATH 200, CSCI 256 will look at the Math side)

😳 👍

## directed graph

## the directed graph generalizes the linked list

– a node in a **directed graph** has references to any number of other nodes
  – nodes are drawn as circles
  – references are drawn as arrows

let's not worry about whether this is allowed

or whether this is allowed

(whether we allow for self-edges, multiple edges, etc. depends on context)
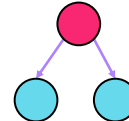
🙂 👍

13

---

# tree

14

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# kinship terminology
## (parent, child, etc.)

15

---

kinship terminology is useful for describing trees

– a node has references to other nodes
  – it is their **parent**
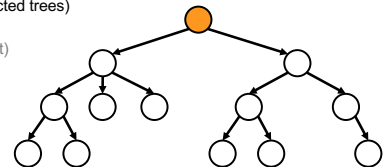  – they are its **children**
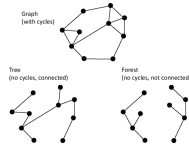
16

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# (directed) tree

17

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a (directed) **tree** is a directed graph that...

– has exactly one node with zero parents (the **root**)
– has no nodes with more than one parent
– has no **cycles** (loops) of any kind
– is **connected** (just one tree,
  not multiple disconnected trees)
  – (otherwise,
    it would be a forest)

18

**note:** not joking

19


Monday Funday

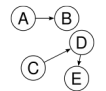20

time for everyone's favorite home game...
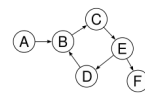
21


**is it a tree?**

yes

**tree rules**
1. exactly one node with zero parents
2. no node with more than one parent
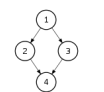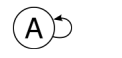3. no **cycles**
4. is **connected**

no
violates 2 & 3

no
violates 2 & 3
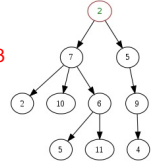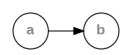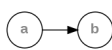
no
violates 1 & 4

no
violates 1 & 3

yes

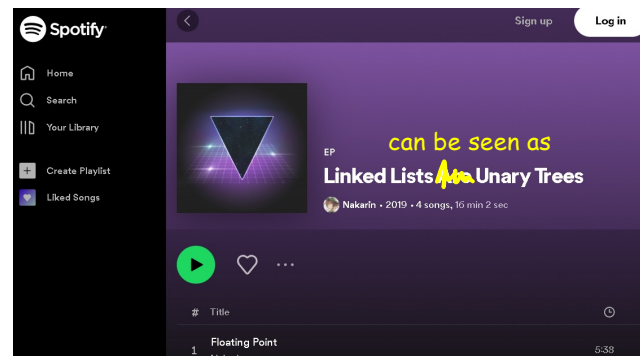22

**is it a tree?**

yes

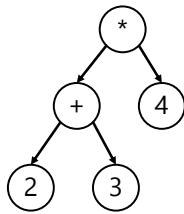

23


can be seen as

24

## uses of trees

simplifying expressions

(2 + 3) * 4

```
      *
     / \
    +   4
   / \
  2   3
```

5 * 4

```
    *
   / \
  5   4
```

20

(20)

!(true && (false || true)

```
        !
        |
       &&
      /  \
   true   ||
         /  \
     false   true
```
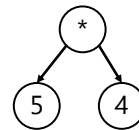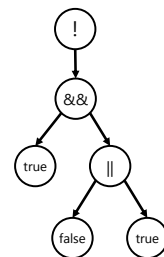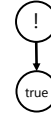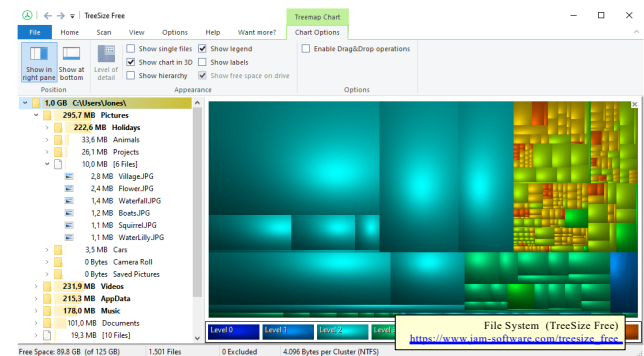
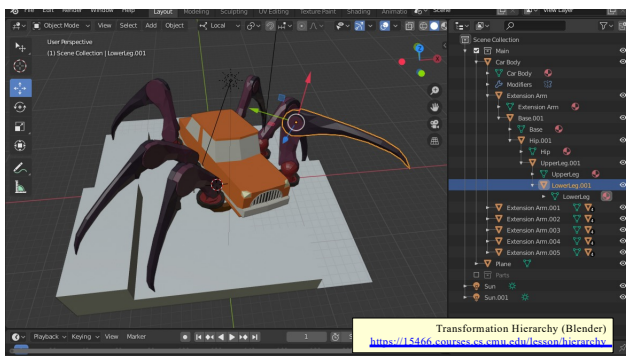!(true && true)
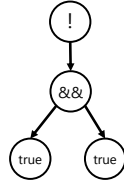


31

!true



32

false



33

and so much more!

34
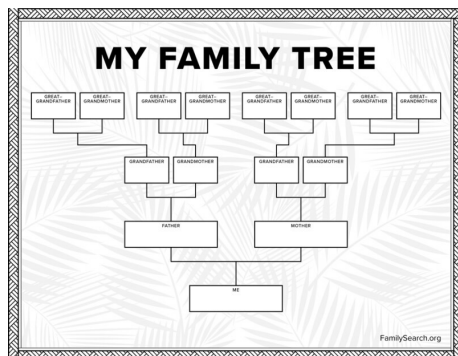
# MY FAMILY TREE



35
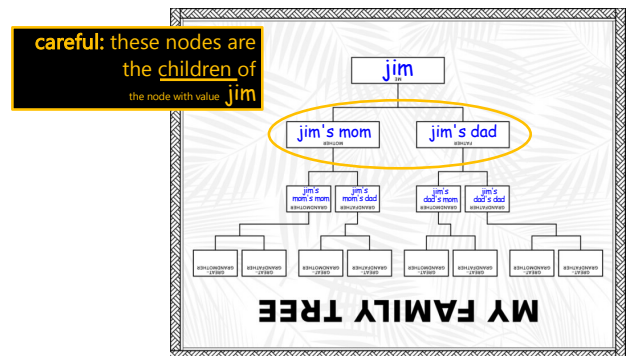


36

**note:**
family trees considered deeply confusing;
let us never talk of them again
🙇

37



File System (TreeSize Free)
https://www.jam-software.com/treesize_free

38



Transformation Hierarchy (Blender)
https://15466.courses.cs.cmu.edu/lesson/hierarchy

39



Rapidly Exploring Random Trees (RRTs)
Randomized Kinodynamic Planning by Steven M. LaValle and James J. Kuffner, Jr., International Journal of Robotics Research, 20(5):378–400, May 2001

40

Hierplane (Mark)

41

[homework preview]

42

## different ways to implement trees

ArrayList<Node> children;

Node leftChild;
Node rightChild;

Node[] children;