CS 225

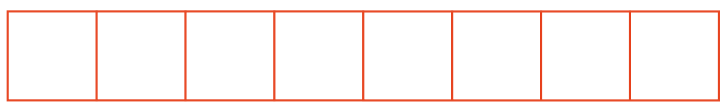
Data Structures

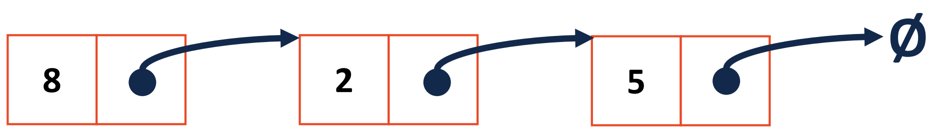
Feb. 18 – Iterators

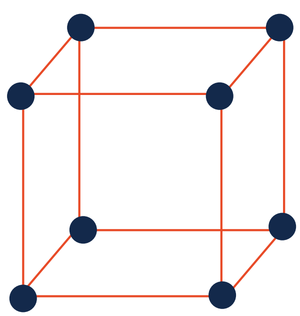
G Carl Evans

Iterators

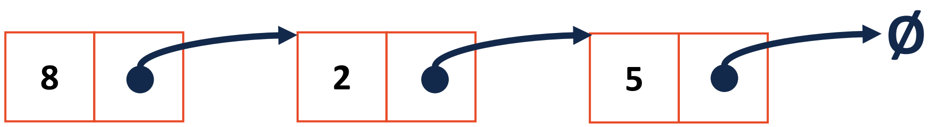
Suppose we want to look through every element in our data structure:

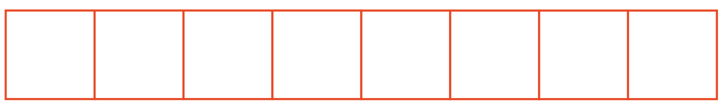


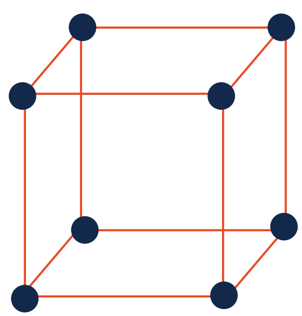




Iterators encapsulated access to our data:







Cur. Location	Cur. Data	Next
`ListNode *`		
`index`		
`(x, y, z)`		

Iterators

Every class that implements an iterator has two pieces:

1. [Implementing Class]:

Iterators

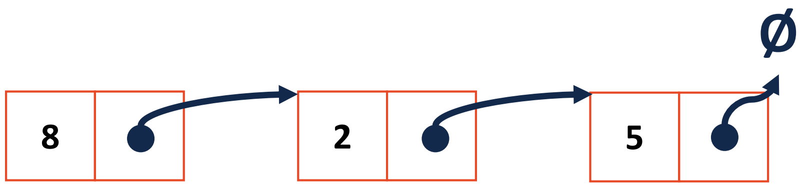
Every class that implements an iterator has two pieces:

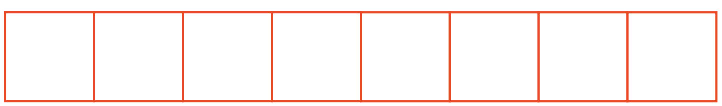
2. [Implementing Class' Iterator]:

- Must have the **base class:** `std::iterator`

- **std::iterator** requires us to minimally implement:

Iterators encapsulated access to our data:





::begin	::end

stlList.cpp

```
#include <list>
#include <string>
#include <iostream>

struct Animal {
  std::string name, food;
  bool big;
  Animal(std::string name = "blob", std::string food = "you", bool big = true) :
    name(name), food(food), big(big) { /* nothing */ }
};

int main() {
  Animal g("giraffe", "leaves", true), p("penguin", "fish", false), b("bear");
  std::vector<Animal> zoo;

  zoo.push_back(g);
  zoo.push_back(p);   // std::vector's insertAtEnd
  zoo.push_back(b);

  for ( std::vector<Animal>::iterator it = zoo.begin(); it != zoo.end(); it++ ) {
    std::cout << (*it).name << " " << (*it).food << std::endl;
  }

  return 0;
}
```

stlList.cpp

```
#include <list>
#include <string>
#include <iostream>

struct Animal {
  std::string name, food;
  bool big;
  Animal(std::string name = "blob", std::string food = "you", bool big = true) :
    name(name), food(food), big(big) { /* nothing */ }
};

int main() {
  Animal g("giraffe", "leaves", true), p("penguin", "fish", false), b("bear");
  std::vector<Animal> zoo;

  zoo.push_back(g);
  zoo.push_back(p);   // std::vector's insertAtEnd
  zoo.push_back(b);

  for ( auto it = zoo.begin(); it != zoo.end(); it++ ) {
    std::cout << (*it).name << " " << (*it).food << std::endl;
  }

  return 0;
}
```

stlList.cpp

```cpp
#include <list>
#include <string>
#include <iostream>

struct Animal {
  std::string name, food;
  bool big;
  Animal(std::string name = "blob", std::string food = "you", bool big = true) :
    name(name), food(food), big(big) { /* none */ }
};

int main() {
  Animal g("giraffe", "leaves", true), p("penguin", "fish", false), b("bear");
  std::vector<Animal> zoo;

  zoo.push_back(g);
  zoo.push_back(p);   // std::vector’s insertAtEnd
  zoo.push_back(b);

  for ( const Animal & animal : zoo ) {
    std::cout << animal.name << " " << animal.food << std::endl;
  }

  return 0;
}
```

For Each and Iterators

```
for ( const TYPE & variable : collection ) {
  // ...
}
```

```
std::vector<Animal> zoo;
…
for ( const Animal & animal : zoo ) {
    std::cout << animal.name << " " << animal.food << std::endl;
}
```

For Each and Iterators

```
for ( const TYPE & variable : collection ) {
  // ...
}
```

```
std::vector<Animal> zoo;
…
for ( const Animal & animal : zoo ) {
    std::cout << animal.name << " " << animal.food << std::endl;
}
```

```
std::multimap<std::string, Animal> zoo;
…
for ( const Animal & animal : zoo ) {
    std::cout << animal.name << " " << animal.food << std::endl;
}
```

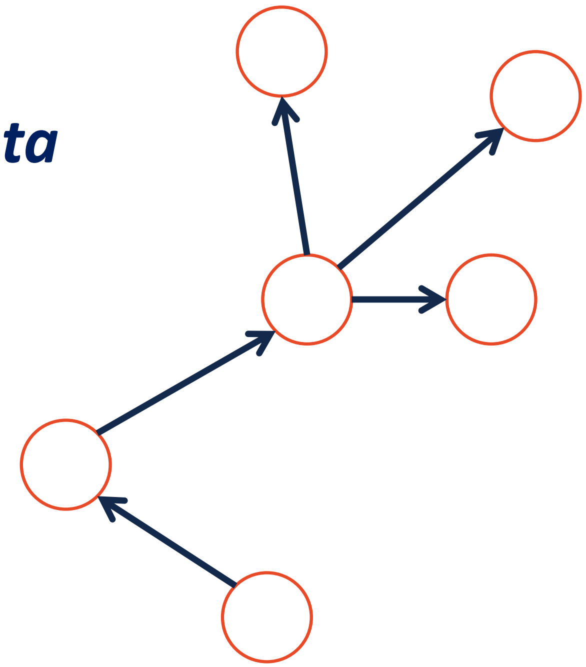
Trees

"The most important non-linear data structure in computer science."

- David Knuth, The Art of Programming, Vol. 1

A tree is:

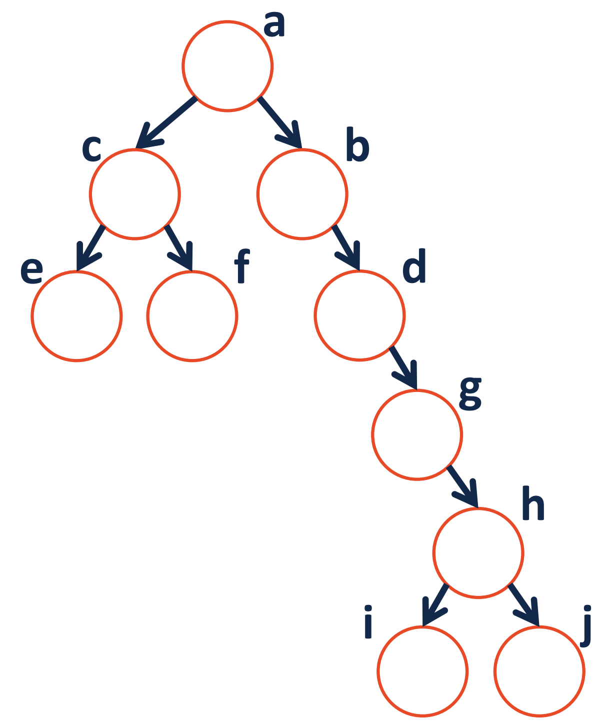
-
-



More Specific Trees

We'll focus on **binary trees**:

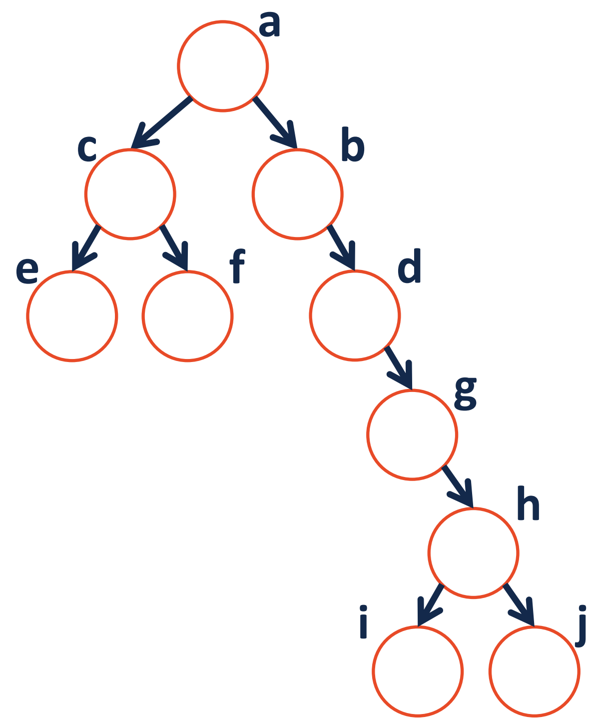
- A binary tree is **rooted** – every node can be reached via a path from the root



More Specific Trees

We’ll focus on **binary trees**:

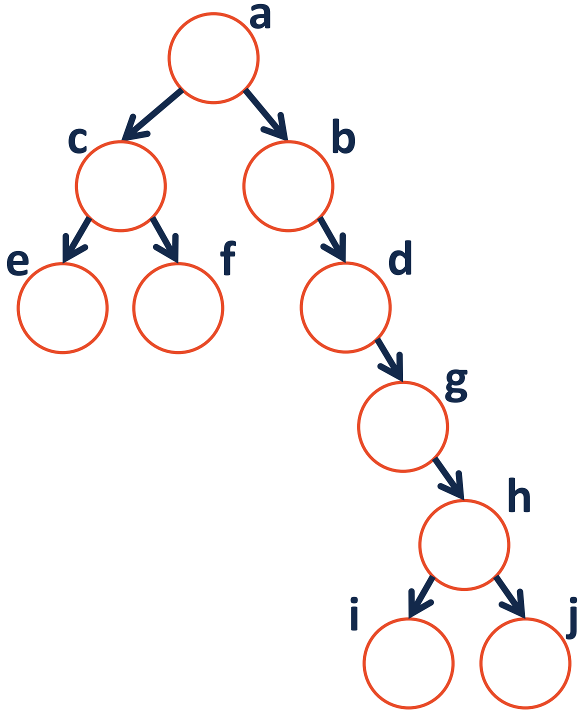
- A binary tree is **acyclic** – there are no cycles within the graph



More Specific Trees

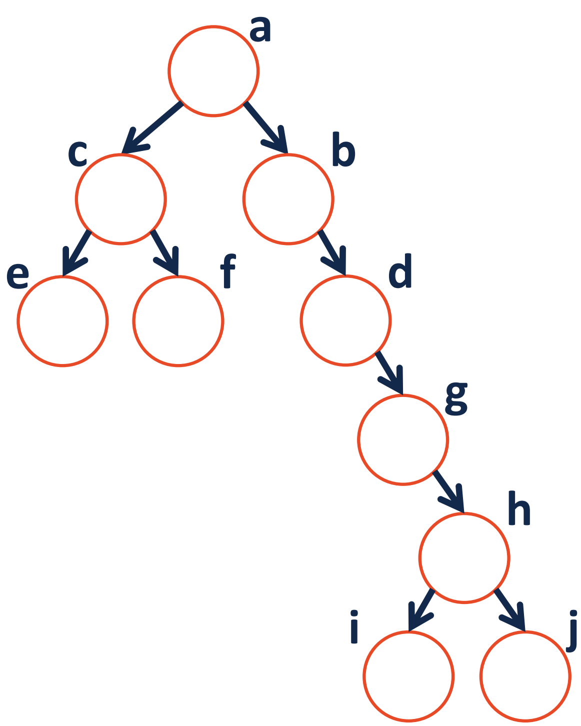
We'll focus on **binary trees**:

- A binary tree contains **two or fewer children** – where one is the "left child" and one is the "right child":



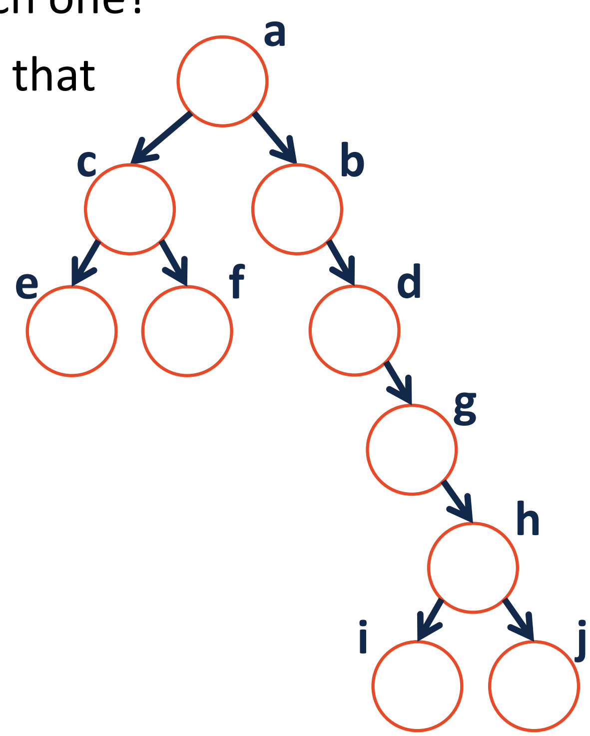
Tree Terminology

- What's the longest **English word** you can make using the **vertex** labels in the tree (repeats allowed)?



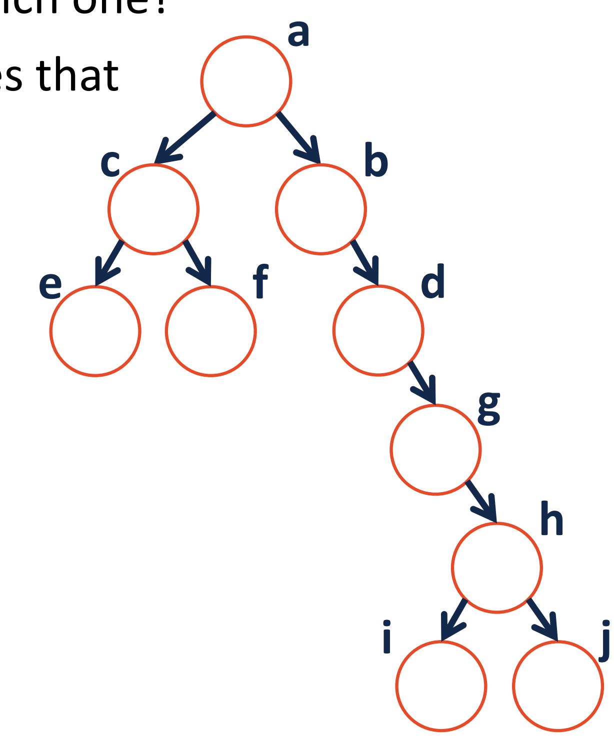
Tree Terminology

- Find an **edge** that is not on the longest **path** in the tree. Give that edge a reasonable name.
- One of the vertices is called the **root** of the tree. Which one?
- Make an "word" containing the names of the vertices that have a **parent** but no **sibling**.
- How many parents does each vertex have?
- Which vertex has the fewest **children**?
- Which vertex has the most **ancestors**?
- Which vertex has the most **descendants**?
- List all the vertices is b's left **subtree**.
- List all the **leaves** in the tree.



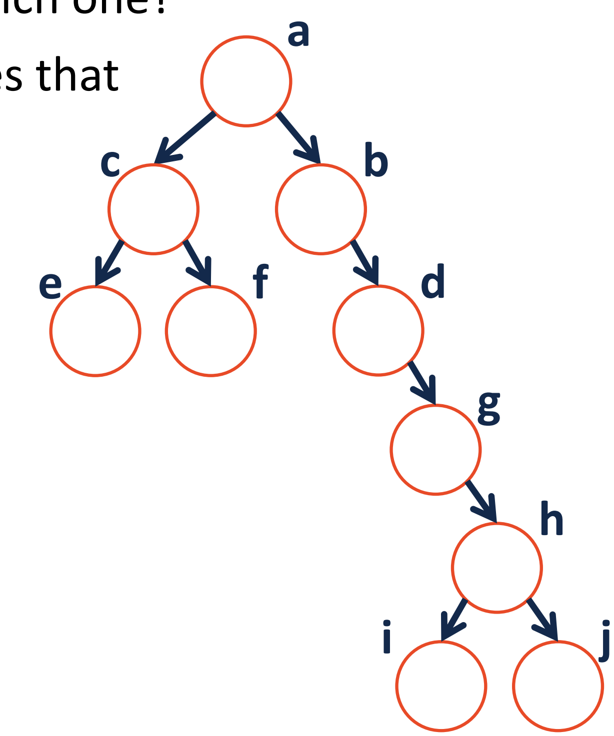
Tree Terminology

- Find an **edge** that is not on the longest **path** in the tree. Give that edge a reasonable name.
- One of the vertices is called the **root** of the tree. Which one?
- Make an "word" containing the names of the vertices that have a **parent** but no **sibling**.
- How many parents does each vertex have?
- Which vertex has the fewest **children**?
- Which vertex has the most **ancestors**?
- Which vertex has the most **descendants**?
- List all the vertices is b's left **subtree**.
- List all the **leaves** in the tree.



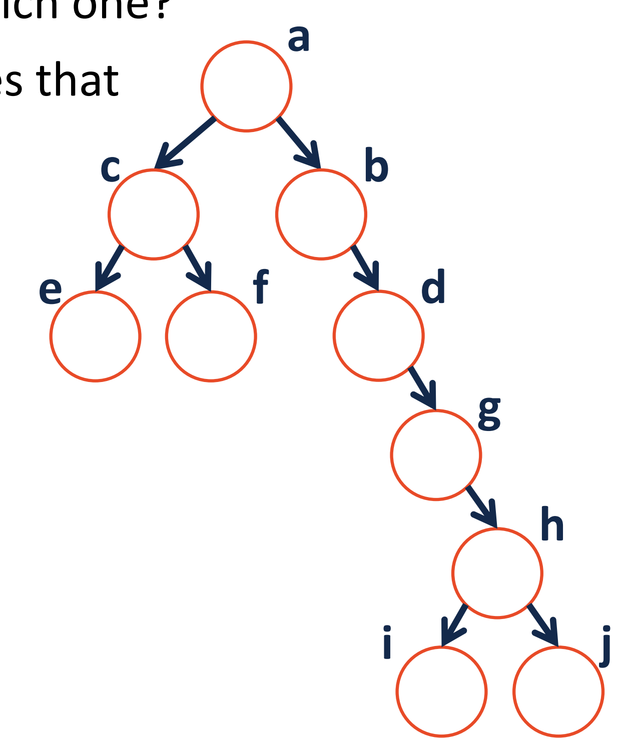
Tree Terminology

- Find an **edge** that is not on the longest **path** in the tree. Give that edge a reasonable name.
- One of the vertices is called the **root** of the tree. Which one?
- Make an "word" containing the names of the vertices that have a **parent** but no **sibling**.
- How many parents does each vertex have?
- Which vertex has the fewest **children**?
- Which vertex has the most **ancestors**?
- Which vertex has the most **descendants**?
- List all the vertices is b's left **subtree**.
- List all the **leaves** in the tree.



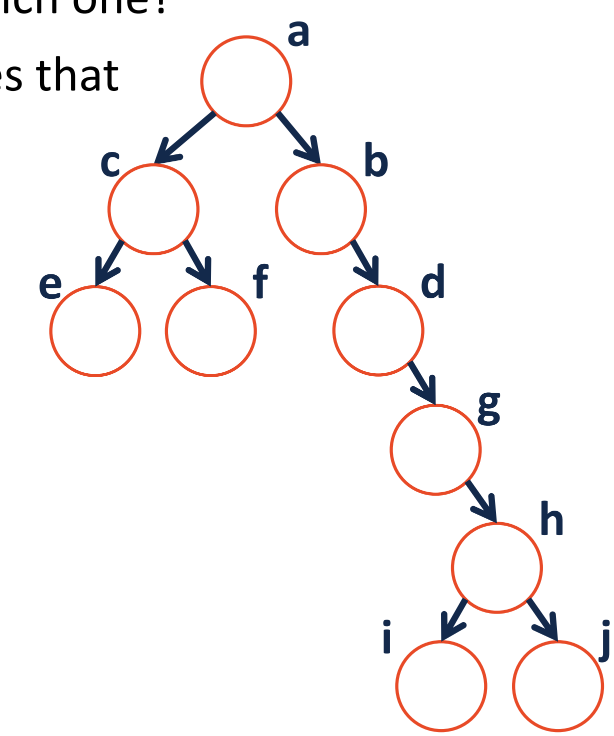
Tree Terminology

- Find an **edge** that is not on the longest **path** in the tree. Give that edge a reasonable name.
- One of the vertices is called the **root** of the tree. Which one?
- Make an "word" containing the names of the vertices that have a **parent** but no **sibling**.
- How many parents does each vertex have?
- Which vertex has the fewest **children**?
- Which vertex has the most **ancestors**?
- Which vertex has the most **descendants**?
- List all the vertices is b's left **subtree**.
- List all the **leaves** in the tree.



Tree Terminology

- Find an **edge** that is not on the longest **path** in the tree. Give that edge a reasonable name.
- One of the vertices is called the **root** of the tree. Which one?
- Make an “word” containing the names of the vertices that have a **parent** but no **sibling**.
- How many parents does each vertex have?
- Which vertex has the fewest **children**?
- Which vertex has the most **ancestors**?
- Which vertex has the most **descendants**?
- List all the vertices is b’s left **subtree**.
- List all the **leaves** in the tree.



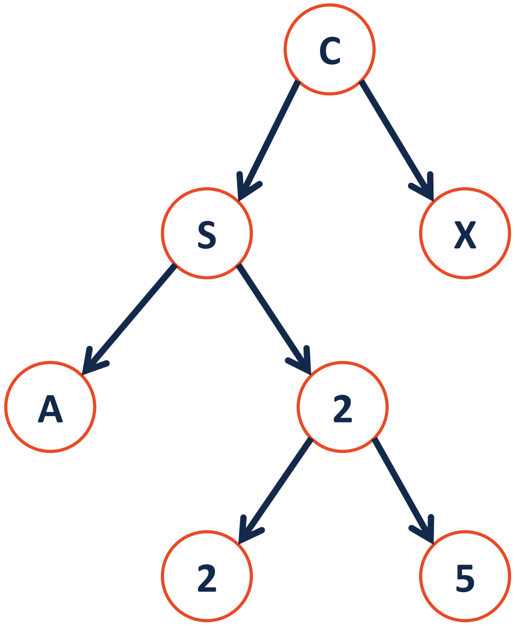
Binary Tree – Defined

A *binary tree* T is either:

-

OR

-

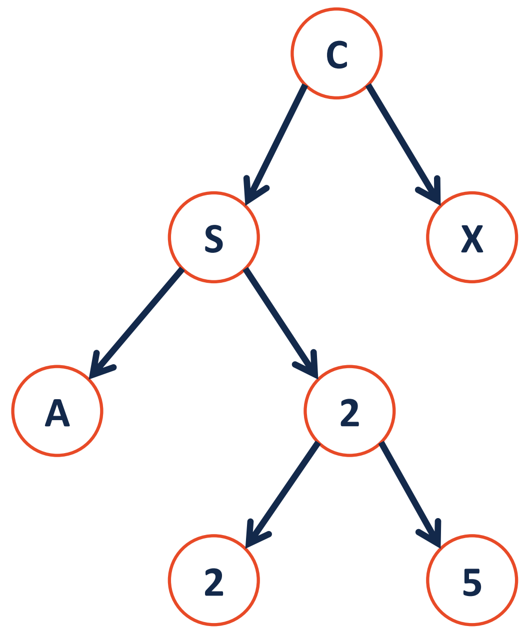


Tree Property: height

height(T): length of the longest path from the root to a leaf

Given a binary tree T:

height(T) =

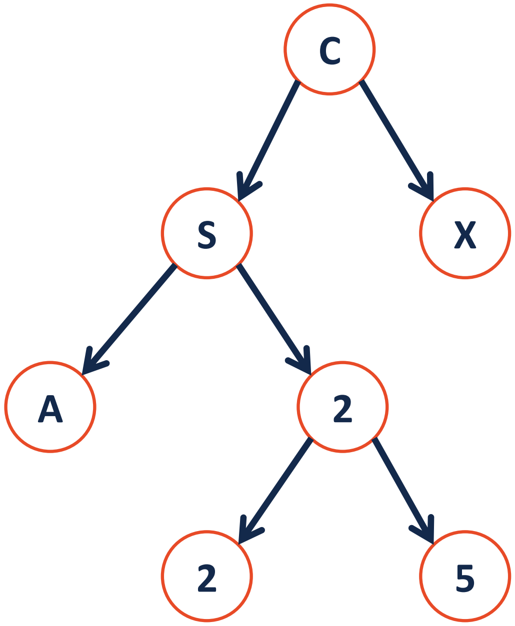


Tree Property: full

A tree ***F*** is **full** if and only if:

1.

2.

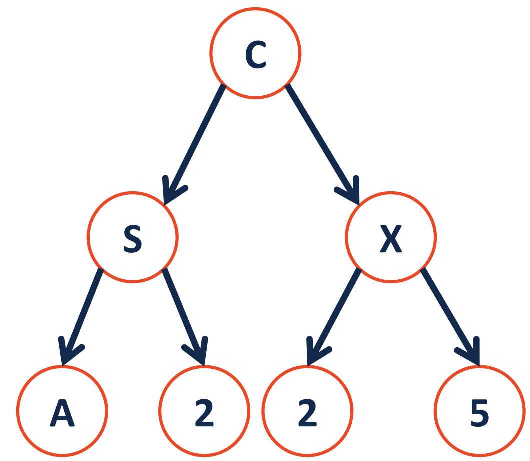


Tree Property: perfect

A **perfect** tree ***P*** is:

1.

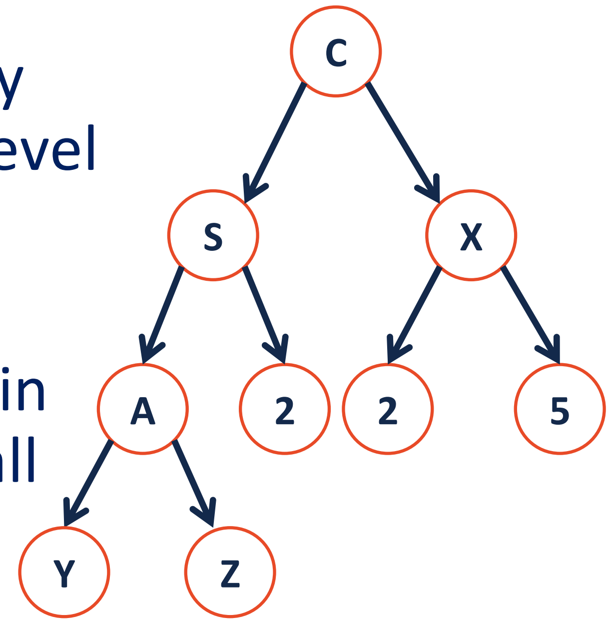
2.



Tree Property: complete

Conceptually: A perfect tree for every level except the last, where the last level if "pushed to the left".

Slightly more formal: For any level k in [0, h-1], k has 2^k nodes. For level h, all nodes are "pushed to the left".



Tree Property: complete

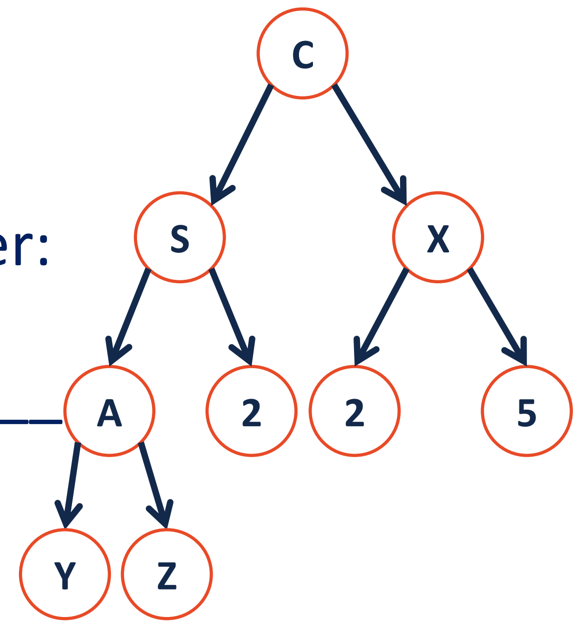
A **complete** tree ***C*** of height **h**, $\mathbf{C_h}$:

1. $\mathbf{C_{-1}} = \{\}$
2. $\mathbf{C_h}$ *(where h>0)* **= {r, $\mathbf{T_L}$, $\mathbf{T_R}$}** and either:

T_L is ___________ and T_R is __________

OR

T_L is ___________ and T_R is __________



Tree Property: complete

Is every **full** tree **complete**?

If every **complete** tree **full**?