CS 225

Data Structures

Sept. 26 – Trees

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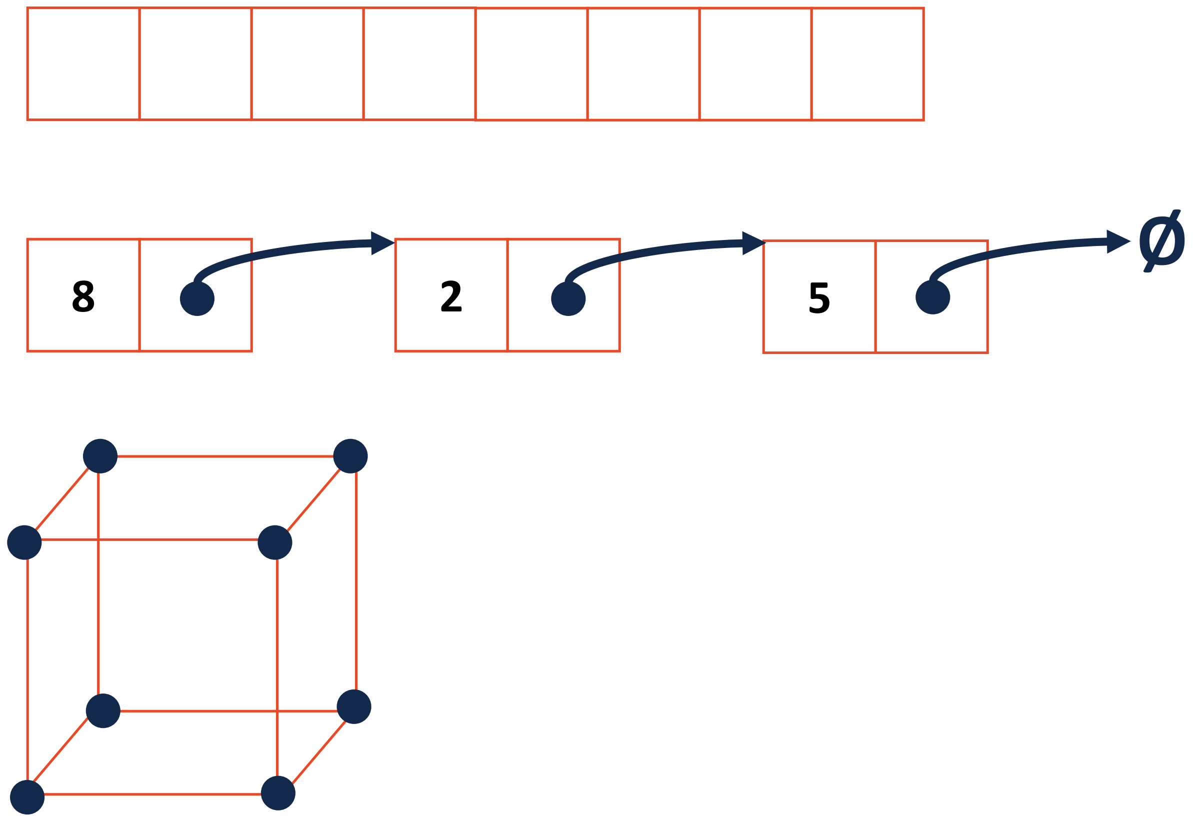
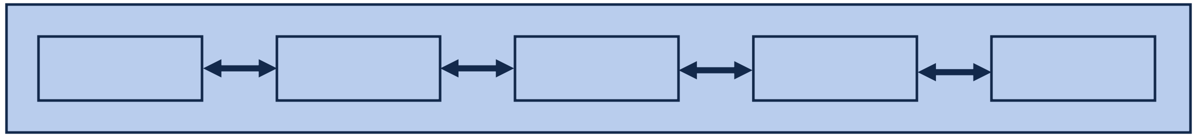
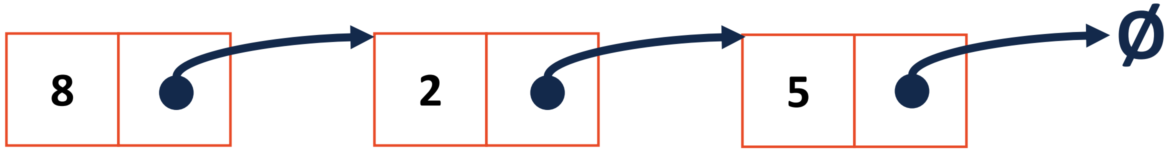
Iterators

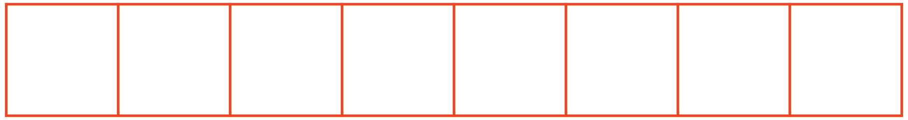
Suppose we want to look through every element in our data structure:

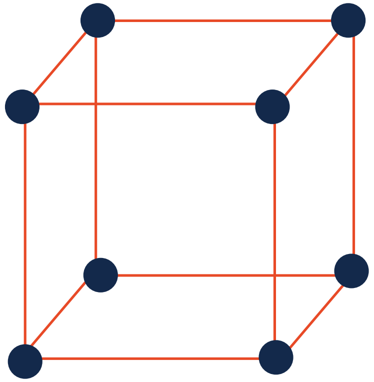


Iterators encapsulated access to our data:









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

Iterators

Every class that implements an iterator has two pieces:

1. [Implementing Class]:

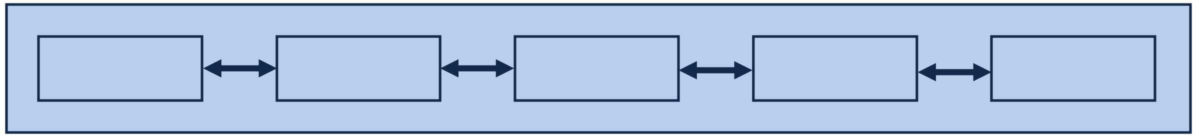
Iterators

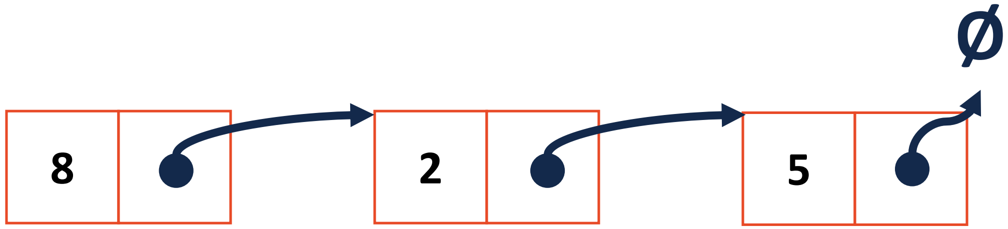
Every class that implements an iterator has two pieces:

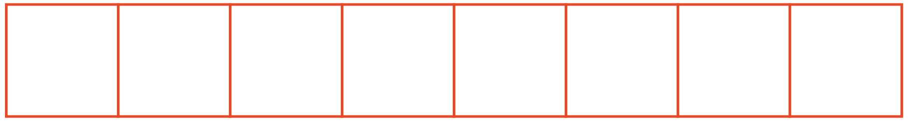
2. [Implementing Class' Iterator]:

- Must have the **base class:** `std::iterator`
- **std::iterator** requires us to minimally implement:

Iterators encapsulated access to our data:







::begin	::end

stlList.cpp

```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;
}
```

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  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 ) {
  // ...
}
```

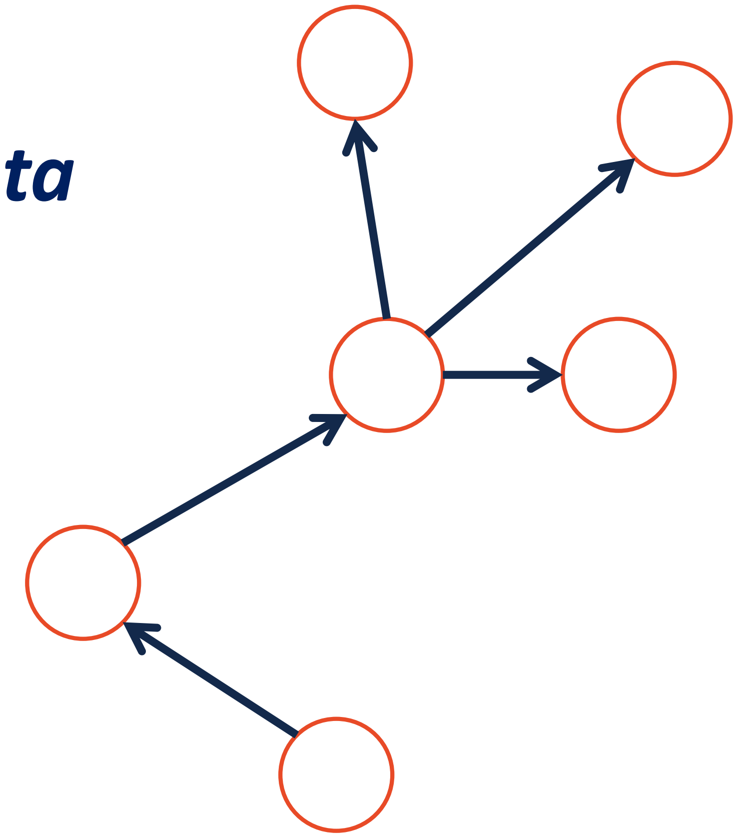
```
std::vector<Animal> zoo;
…
for ( const Animal & animal : zoo ) {
    std::cout << animal.name << " " << animal.food << std::endl;
}
```

```
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."

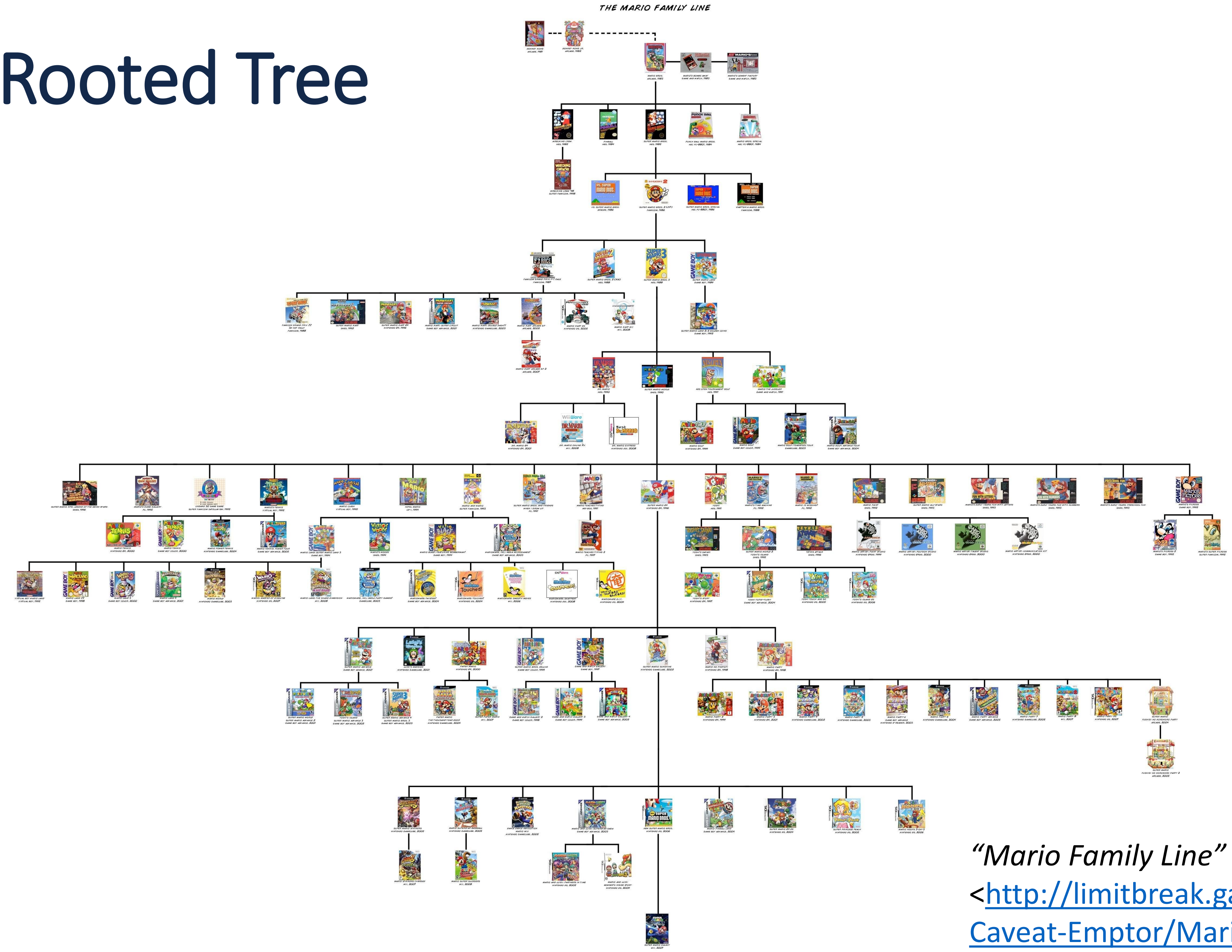
- David Knuth, The Art of Programming, Vol. 1



A tree is:

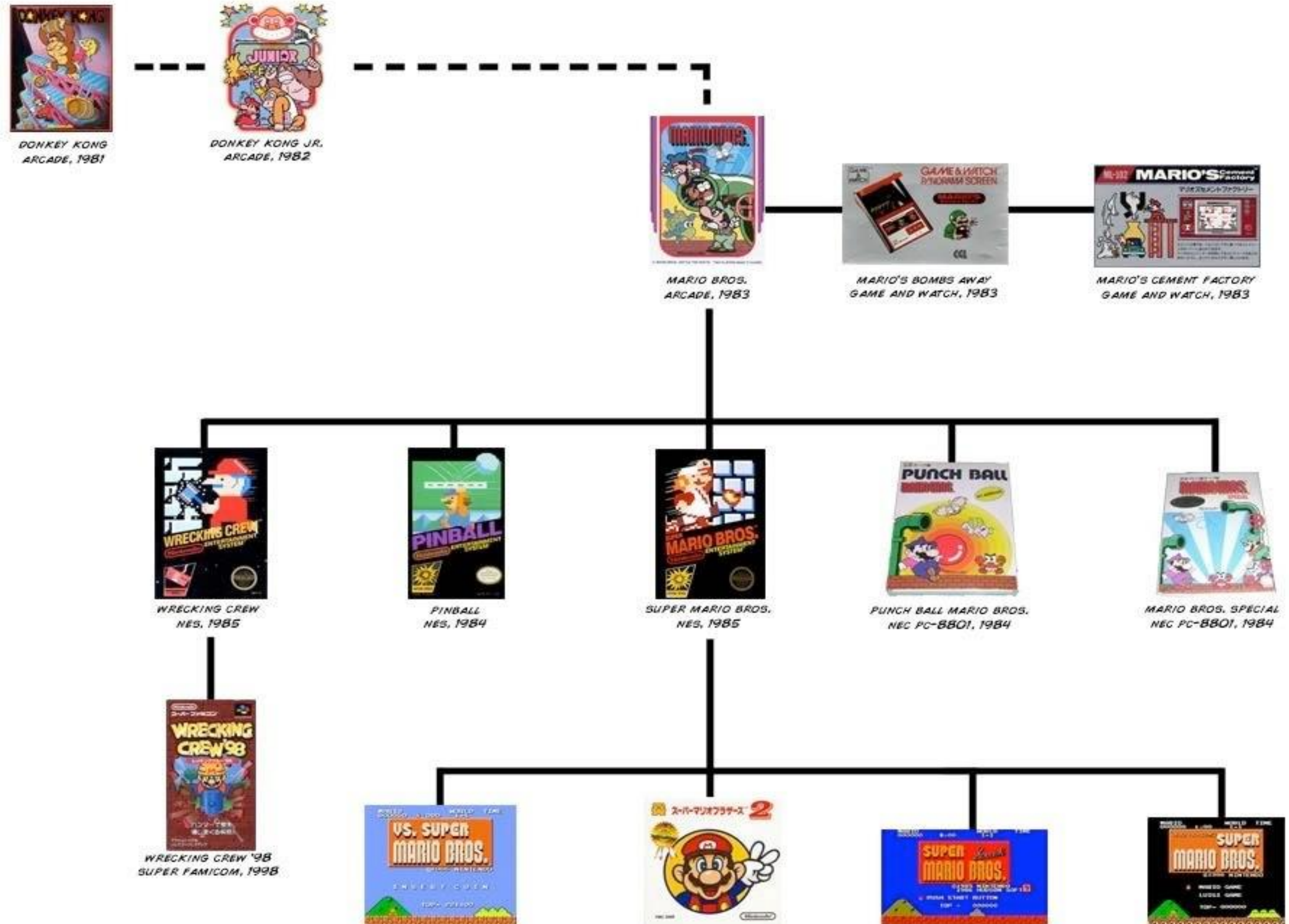
-
-

A Rooted Tree

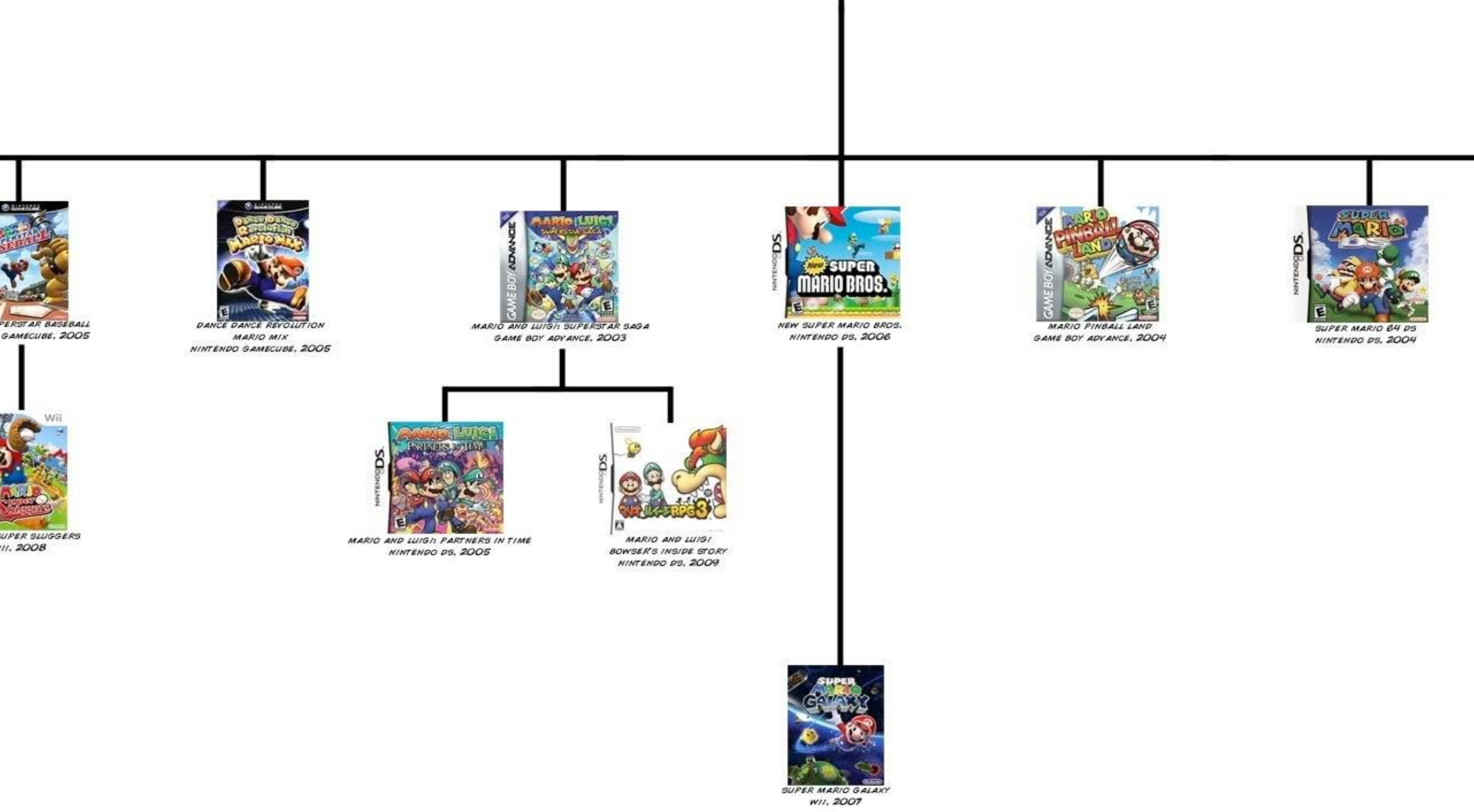


“Mario Family Line”
<http://limitbreak.gameriot.com/blogs/Caveat-Emptor/Mario-Family-Line>

THE MARIO FAMILY LINE



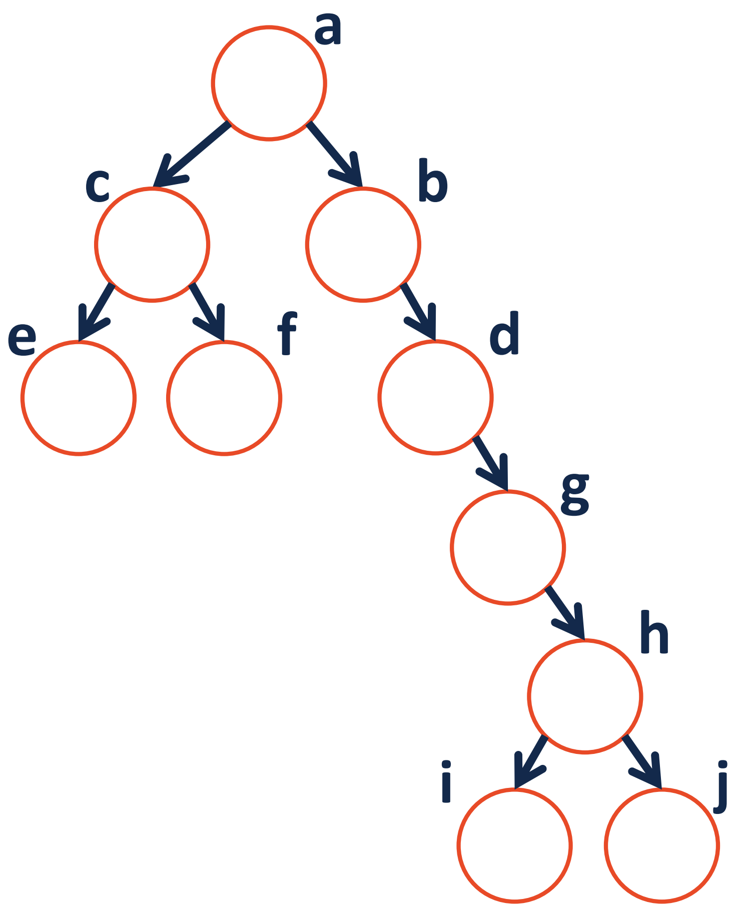

SUPER MARIO RPG: LEGEND OF THE SEVEN STARS
SNES, 1996
MARIO'S GAME GALLERY
PC, 1995
UNDAKE 30 SAME GAME
SUPER FAMICOM SATELLAVIEW, 1995
MARIO'S TENNIS
VIRTUAL BOY, 1995
MARIO CLASH
VIRTUAL BOY,
MARIO TENNIS
NINTENDO 64, 2000
MARIO TENNIS
GAME BOY COLOR, 2000
MARIO POWER TENNIS
NINTENDO GAMECUBE, 2004
MARIO TENNIS: POWER TOUR
GAME BOY ADVANCE, 2005
WARIO LAND: SUPER MARIO LAND 3
GAME BOY, 1994
VIRTUAL BOY WARIO LAND
VIRTUAL BOY, 1995
WARIO LAND II
GAME BOY, 1998
WARIO LAND 3
GAME BOY COLOR, 2000
WARIO LAND 4
GAME BOY ADVANCE, 2001
WARIO WORLD
NINTENDO GAMECUBE, 2003
WARIO: MASTER OF DISGUISE
NINTENDO DS, 2007
WARIO LAND: THE SHAKE DIMENSION
WII, 2008


PERSTAR BASEBALL
GAMECUBE, 2005
DANCE DANCE REVOLUTION
MARIO MIX
NINTENDO GAMECUBE, 2005
MARIO AND LUIGI: SUPERSTAR SAGA
GAME BOY ADVANCE, 2003
NEW SUPER MARIO BROS.
NINTENDO DS, 2006
MARIO PINBALL LAND
GAME BOY ADVANCE, 2004
SUPER MARIO 64 DS
NINTENDO DS, 2004
UPER SLUGGERS
II, 2008
MARIO AND LUIGI: PARTNERS IN TIME
NINTENDO DS, 2005
MARIO AND LUIGI
BOWSER'S INSIDE STORY
NINTENDO DS, 2009
SUPER MARIO GALAXY
WII, 2007

More Specific Trees

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

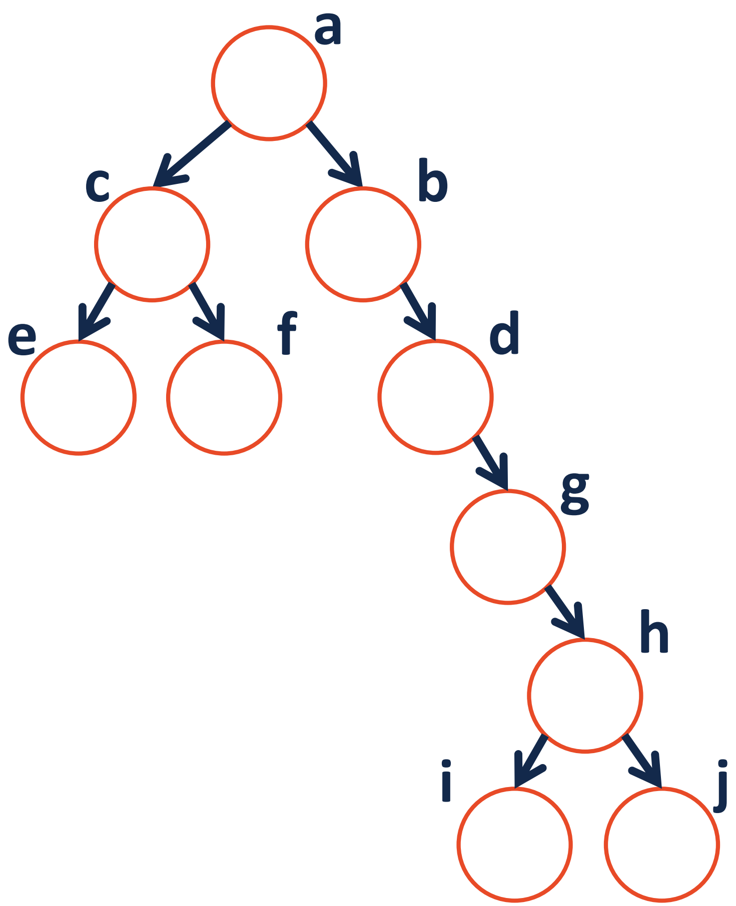
- A binary tree is **rooted** – every node can be reached via a path from the root



More Specific Trees

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

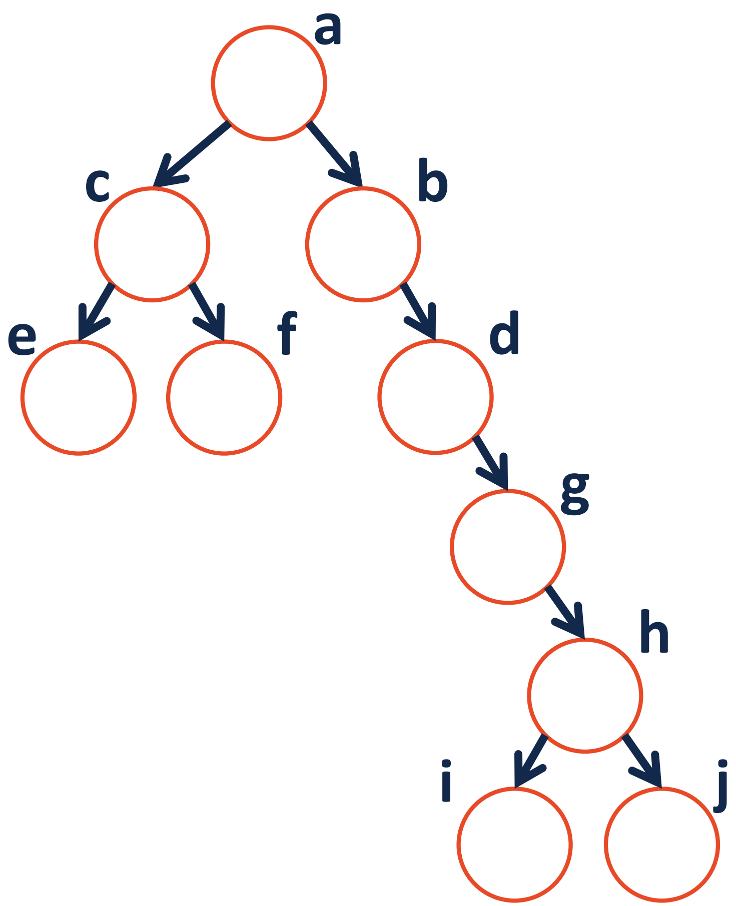
- A binary tree is **acyclic** – there are no cycles within the graph



More Specific Trees

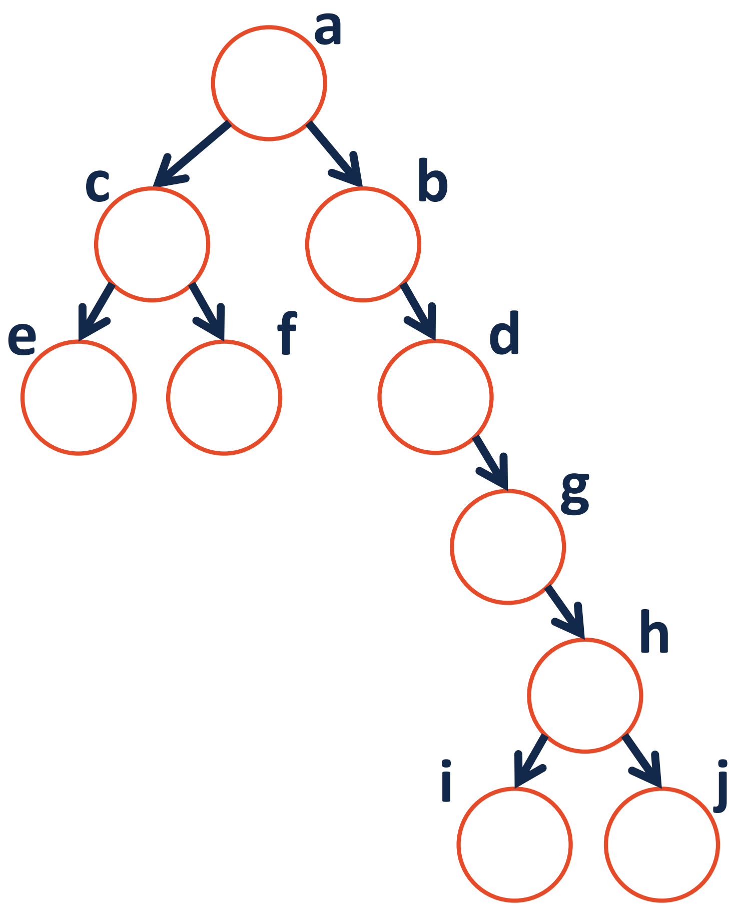
We'll focus on **binary trees**:

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



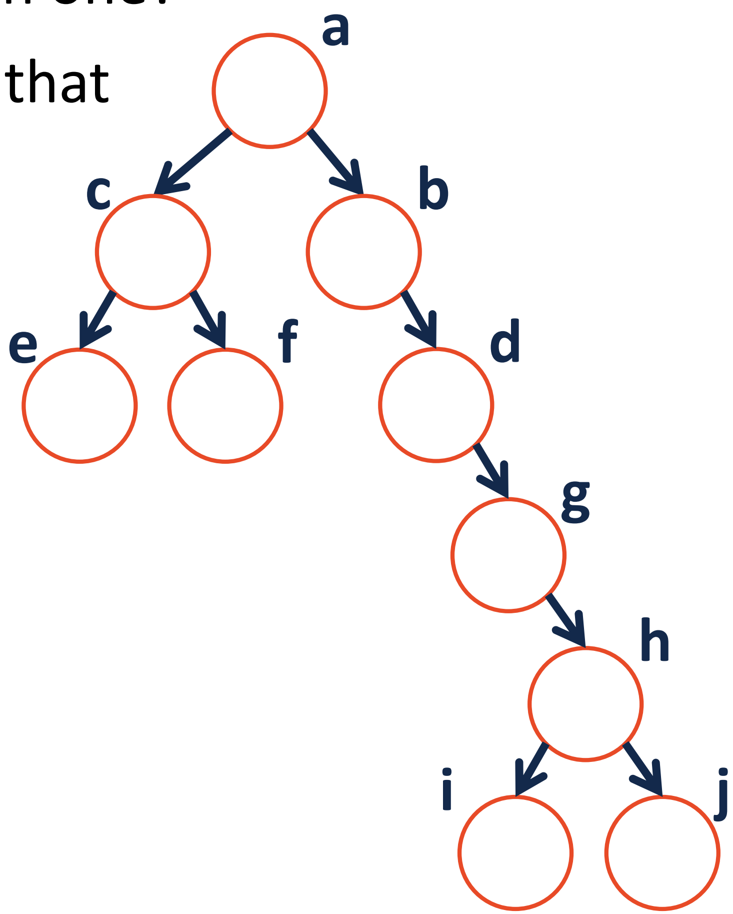
Tree Terminology

- 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.



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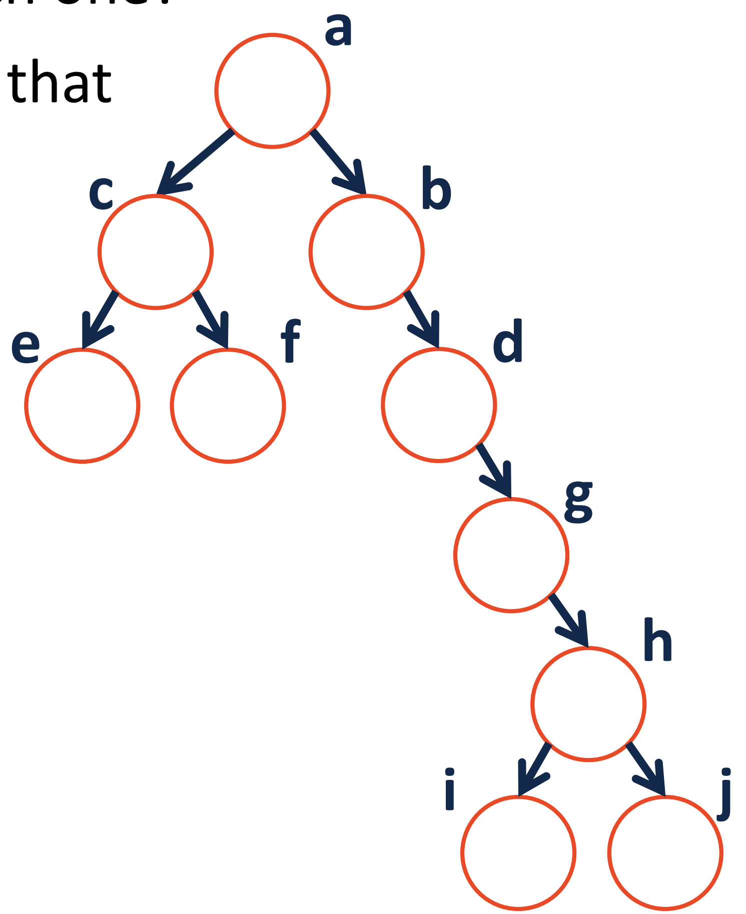

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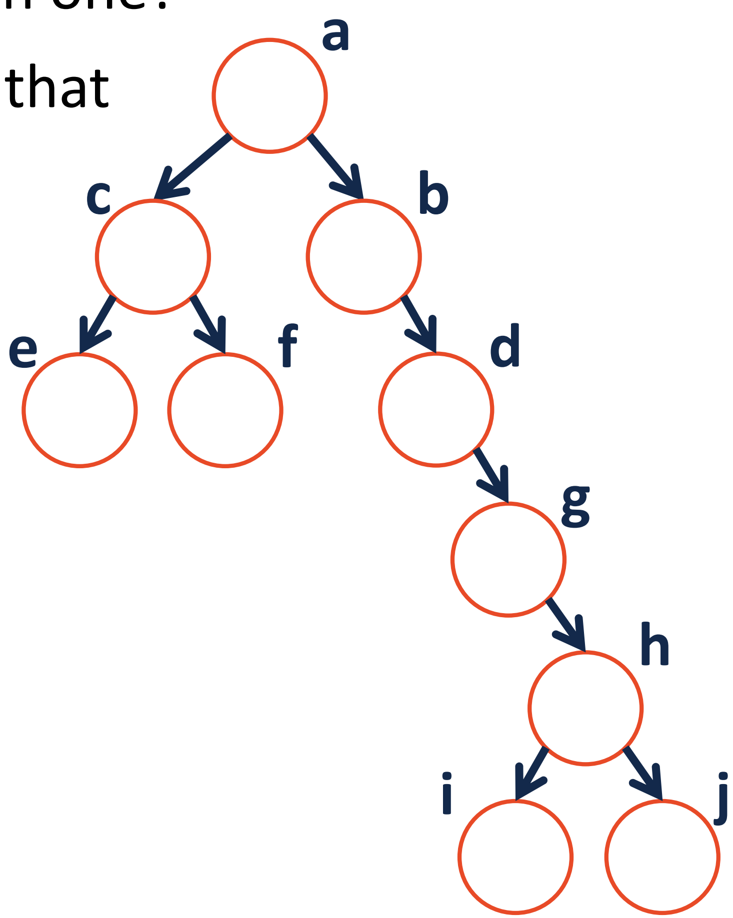

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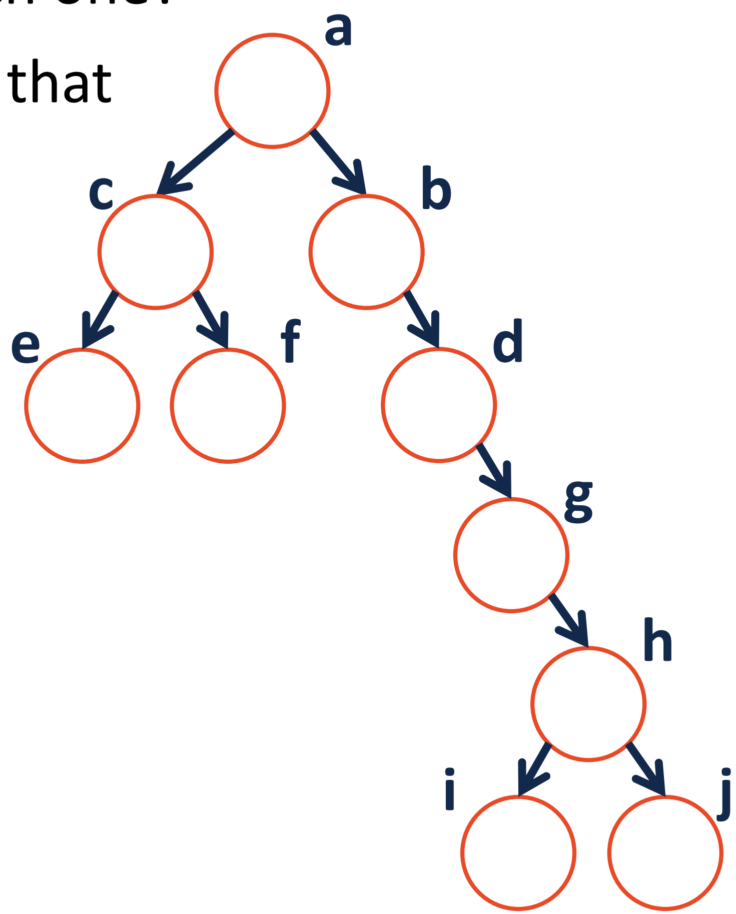

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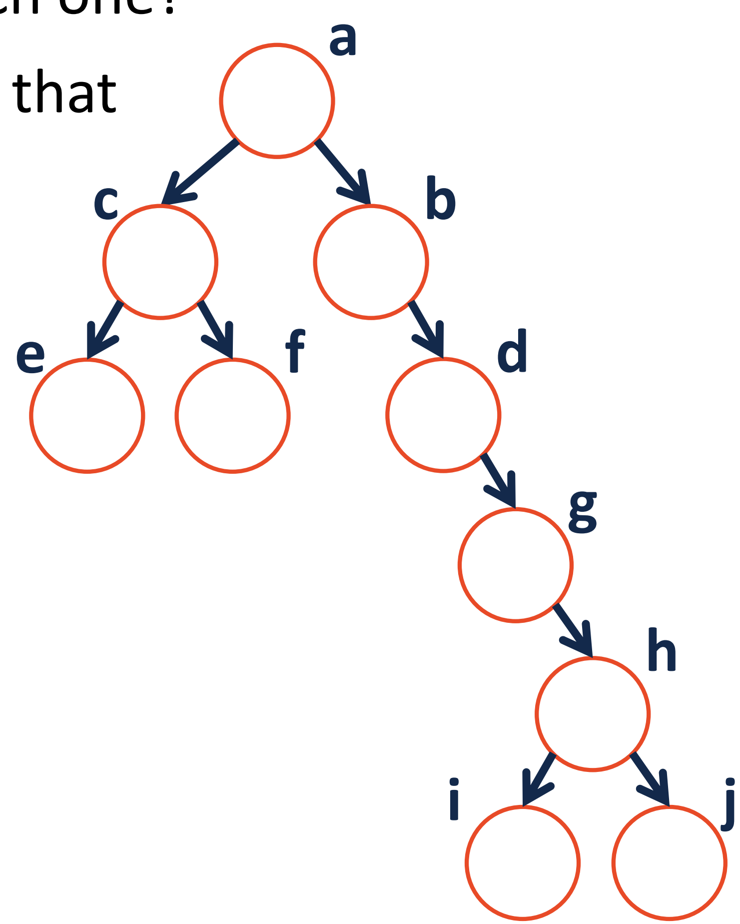


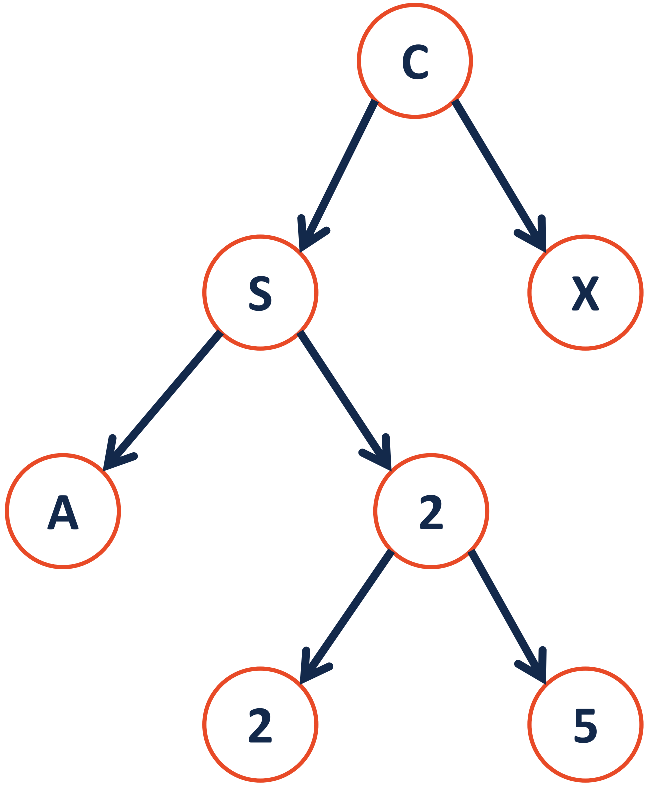
Binary Tree – Defined

A *binary tree* T is either:

-

OR

-

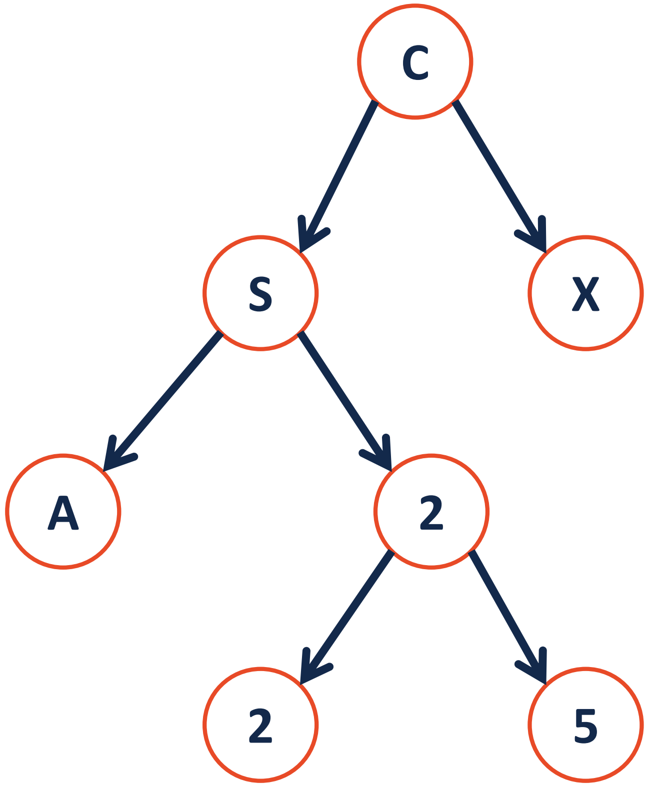


Tree Property: height

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

Given a binary tree T:

height(T) =

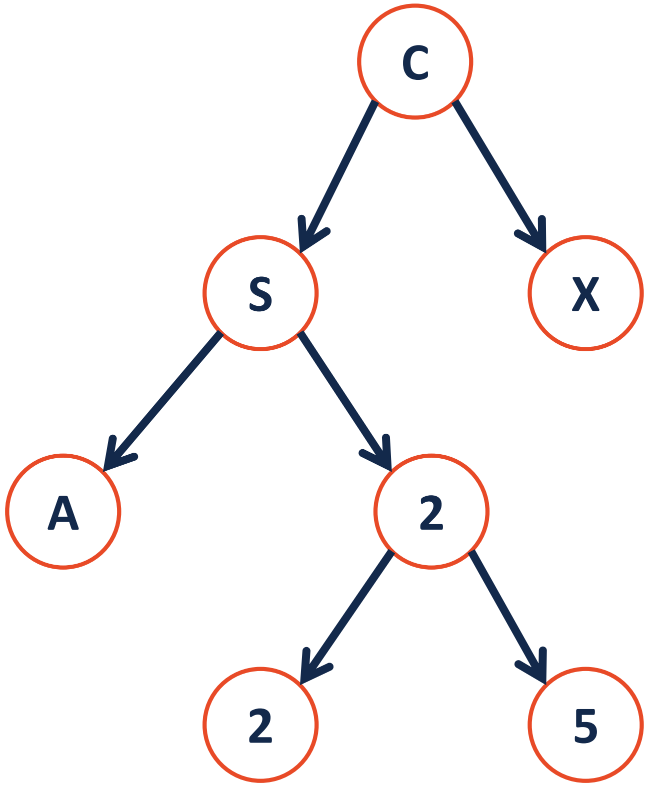


Tree Property: full

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

1.

2.

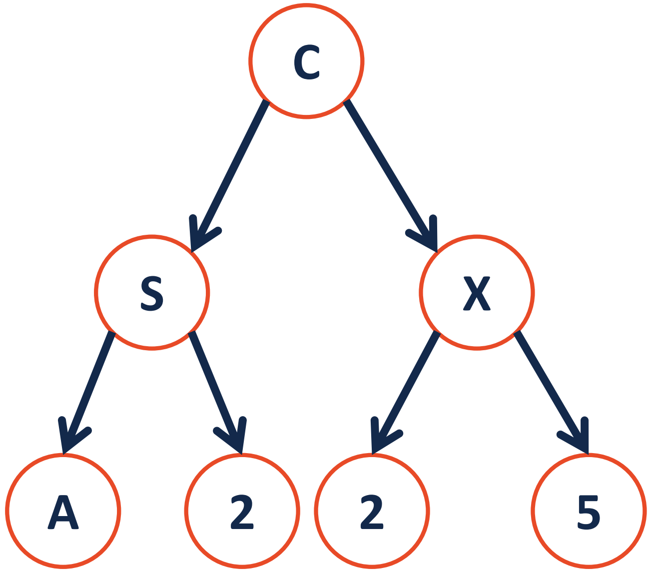


Tree Property: perfect

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

1.

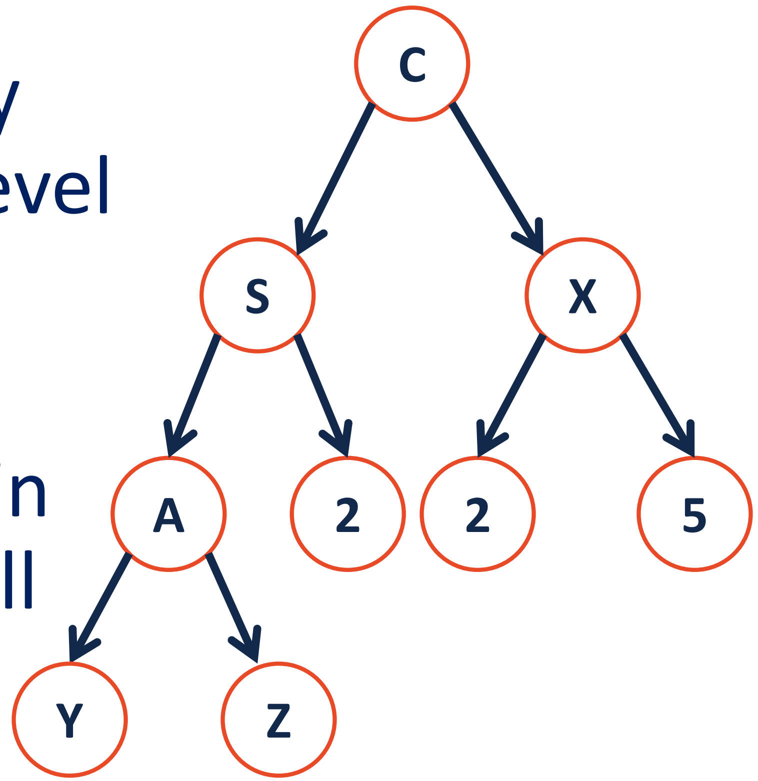
2.



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

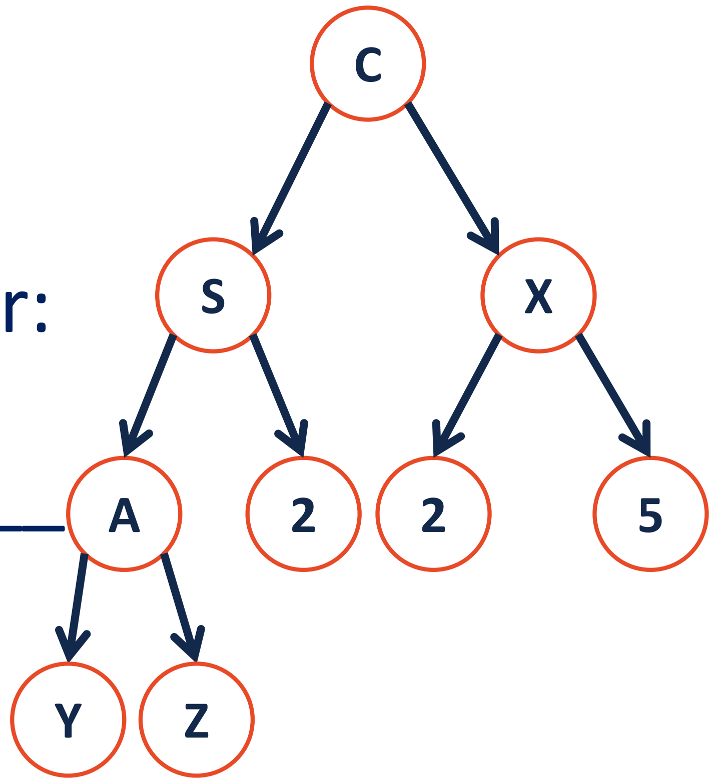
A **complete** tree ***C*** of height **h**, $\mathbf{C_h}$:

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