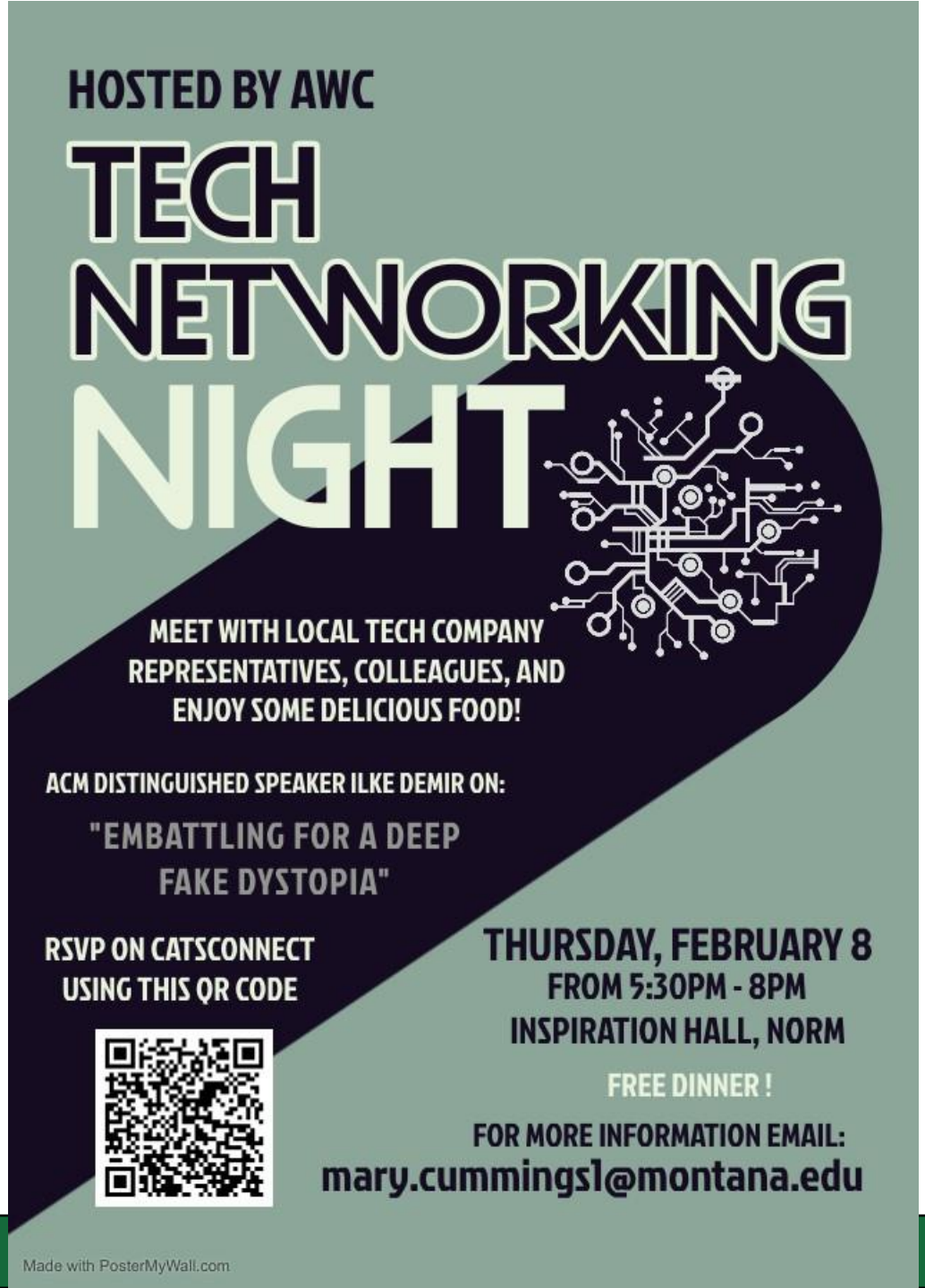
CSCI 232:
Data Structures and Algorithms

Tree Traversal

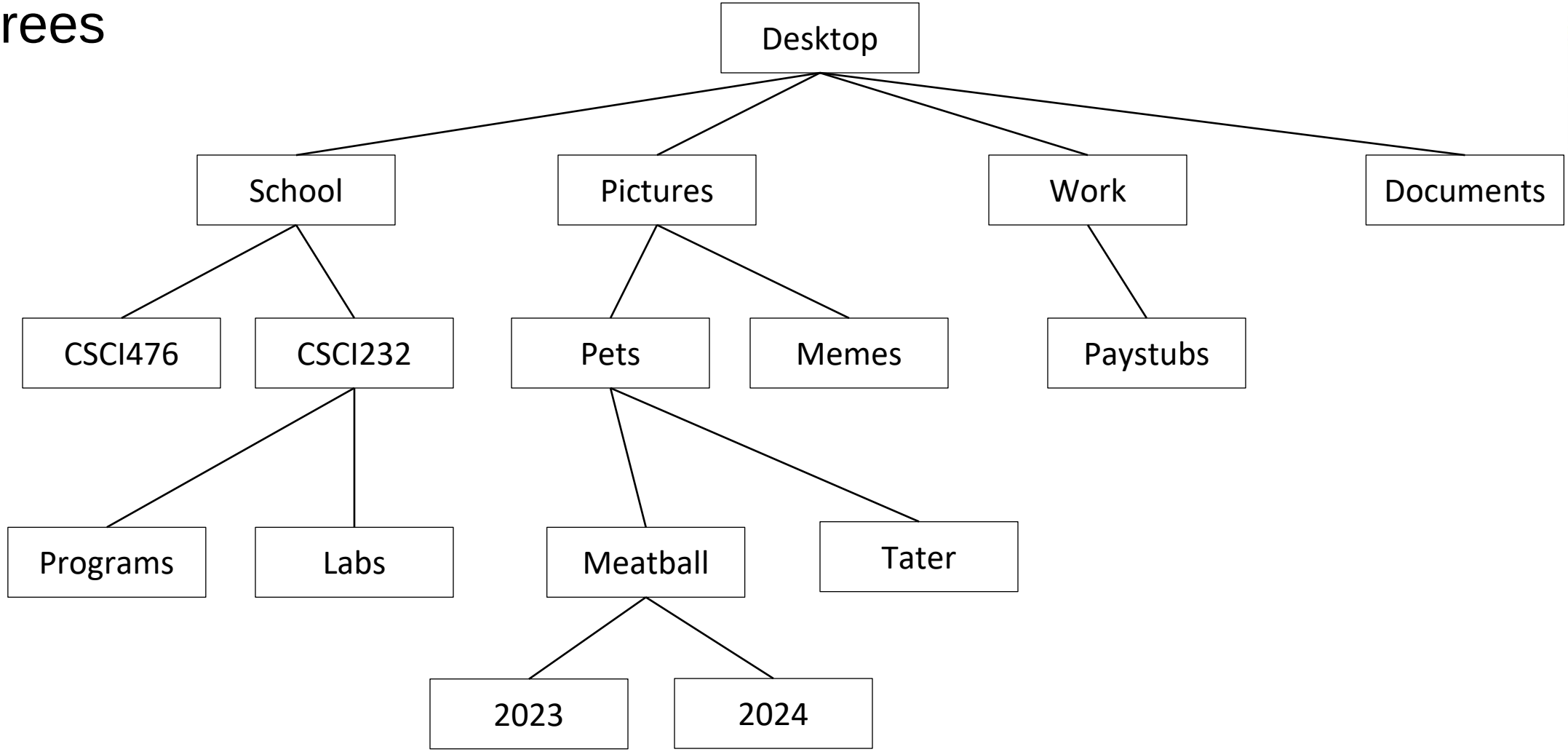
Reese Pearsall

Spring 2024

Announcements

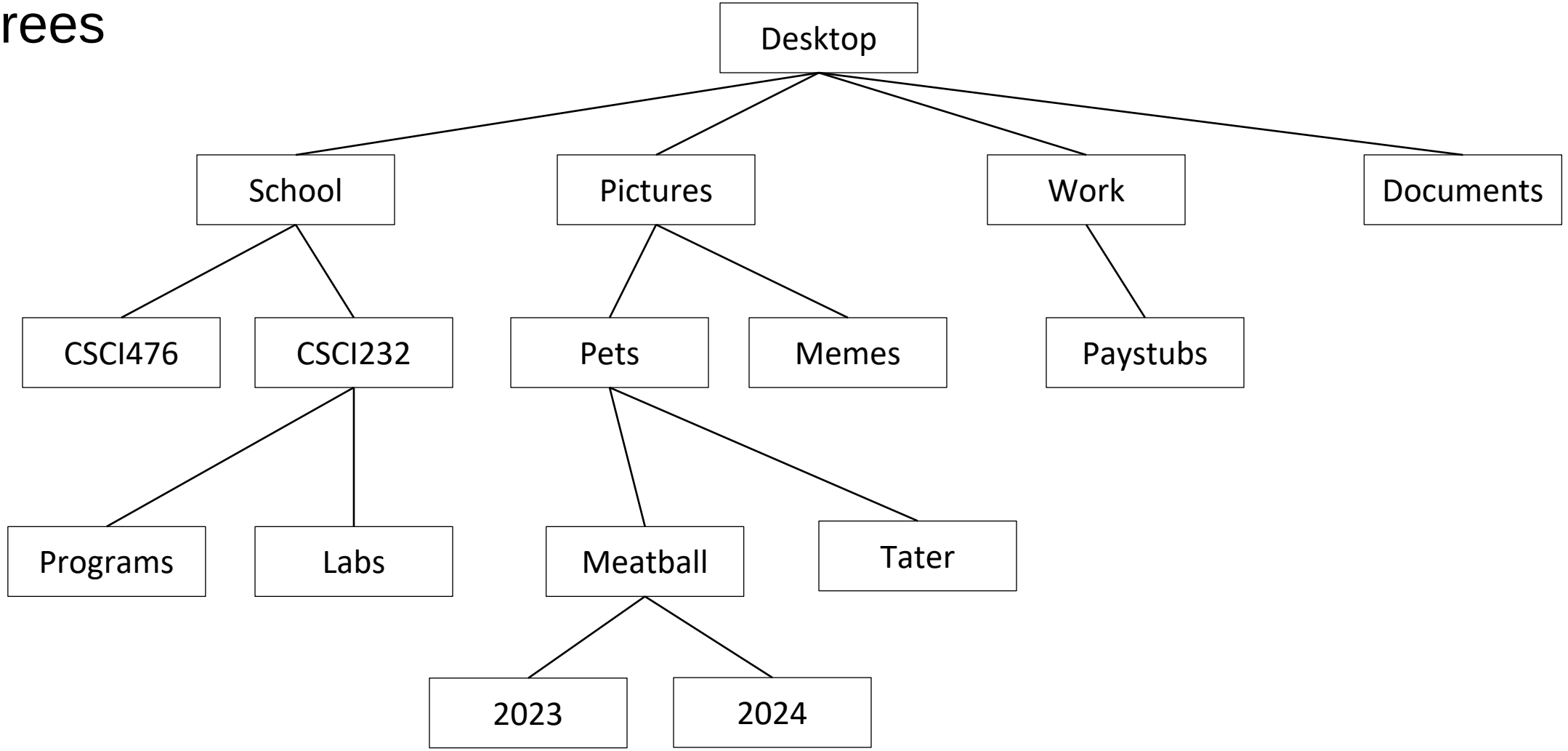


Trees



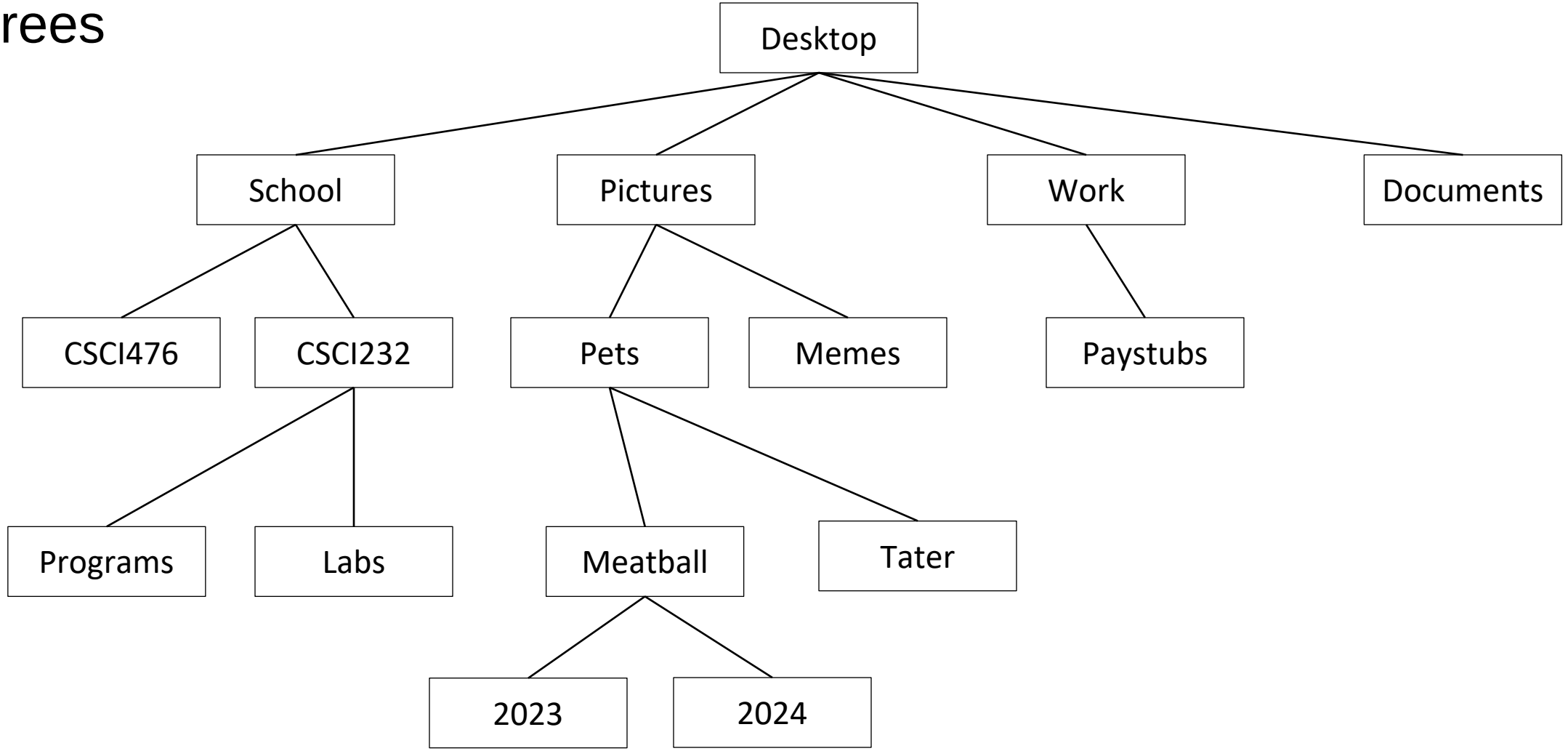
Trees are data structures used to store elements hierarchically
(not linear like arrays and linked lists)

Trees



How could you search for a value in a tree?

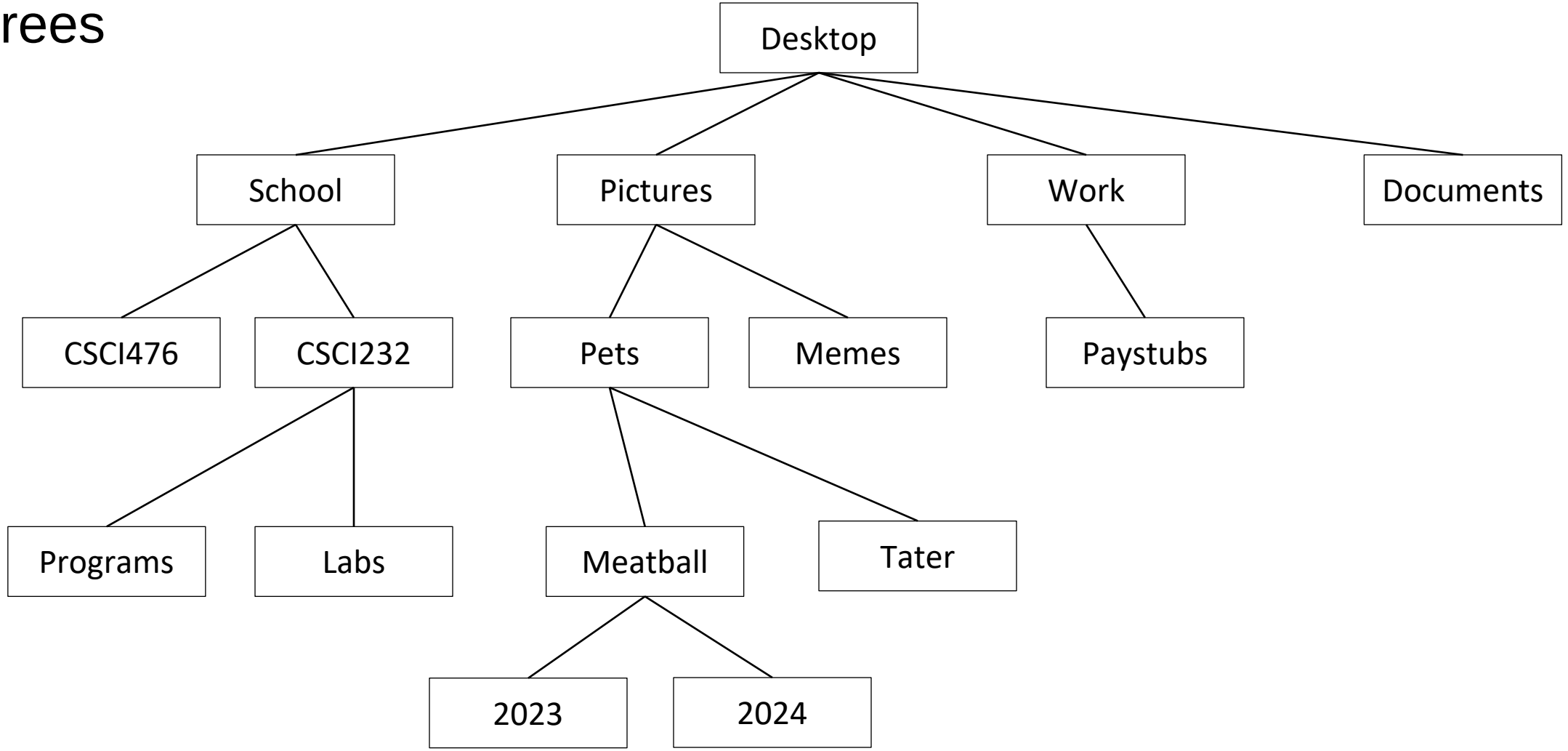
Trees



How could you search for a value in a tree?

1. **Breadth-first**. Visit all nodes at the same depth before progressing to next depth

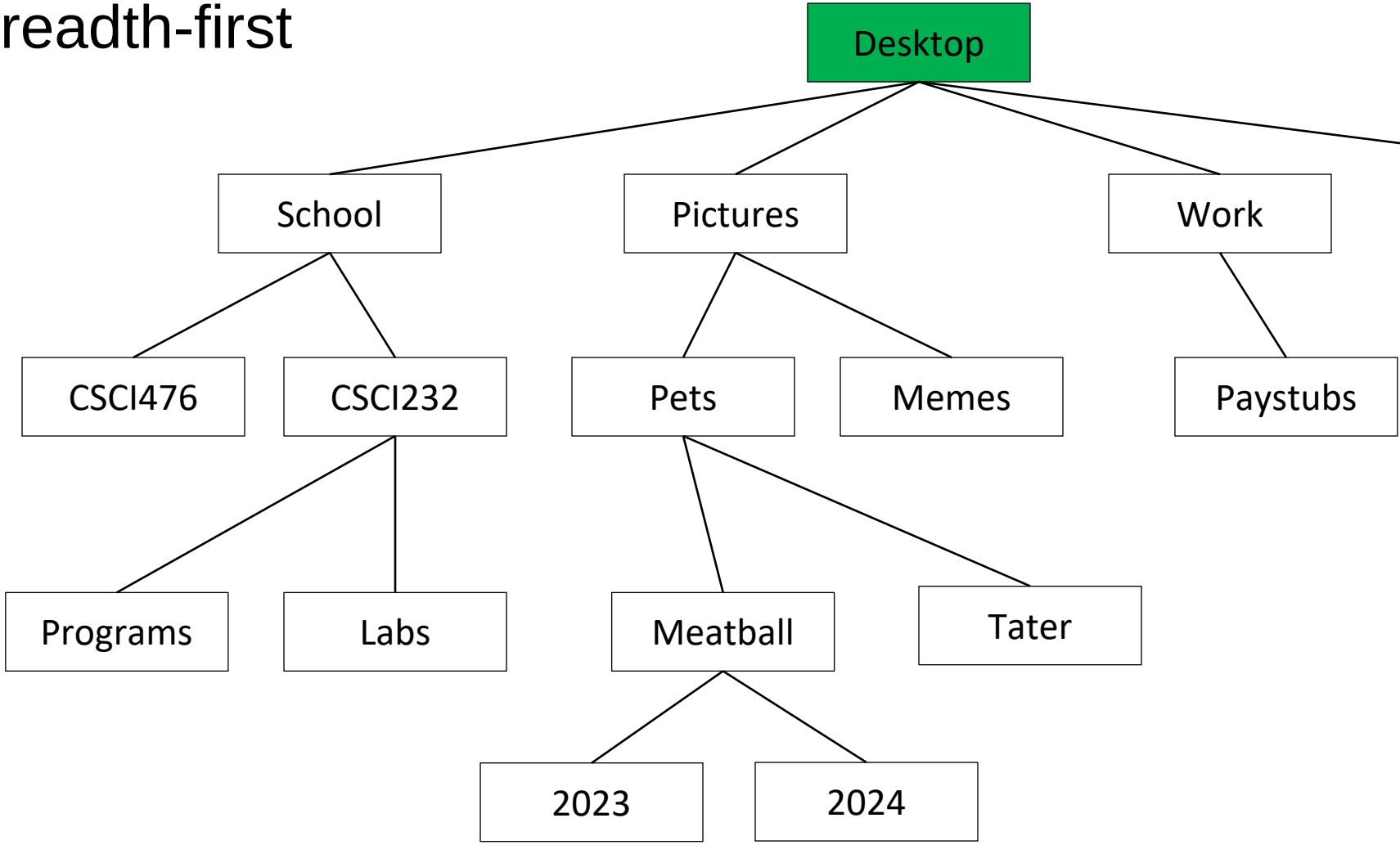
Trees



How could you search for a value in a tree?

2. **Depth-first**. Explores full root-leaf paths

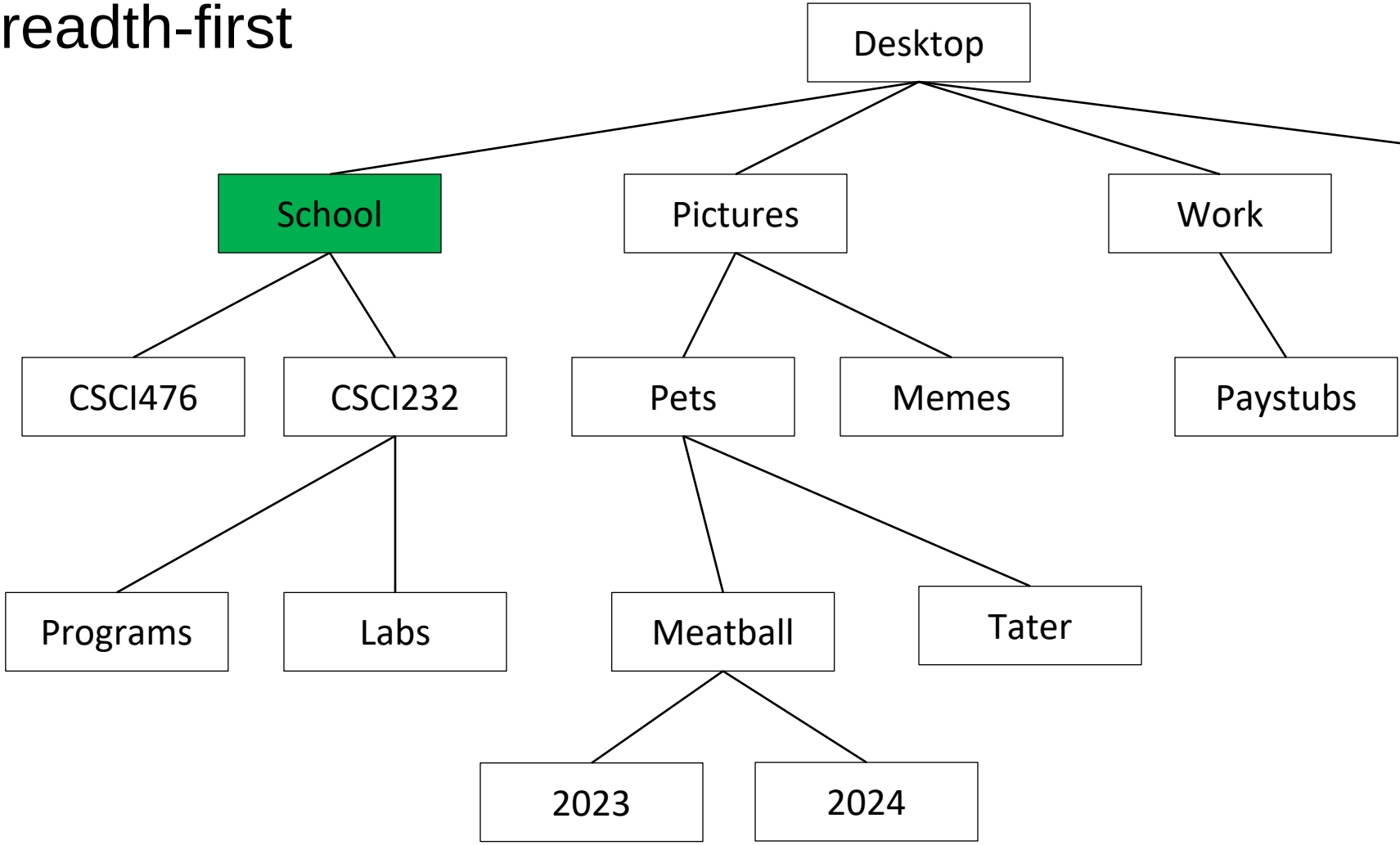
Breadth-first



1. **Visit Root**

"Visit" is a generic action. The actual action depends on what the application is (ex: print node, compare, update)

Breadth-first



1. **Visit Root**
2. **Visit all depth 1 nodes (in order)**

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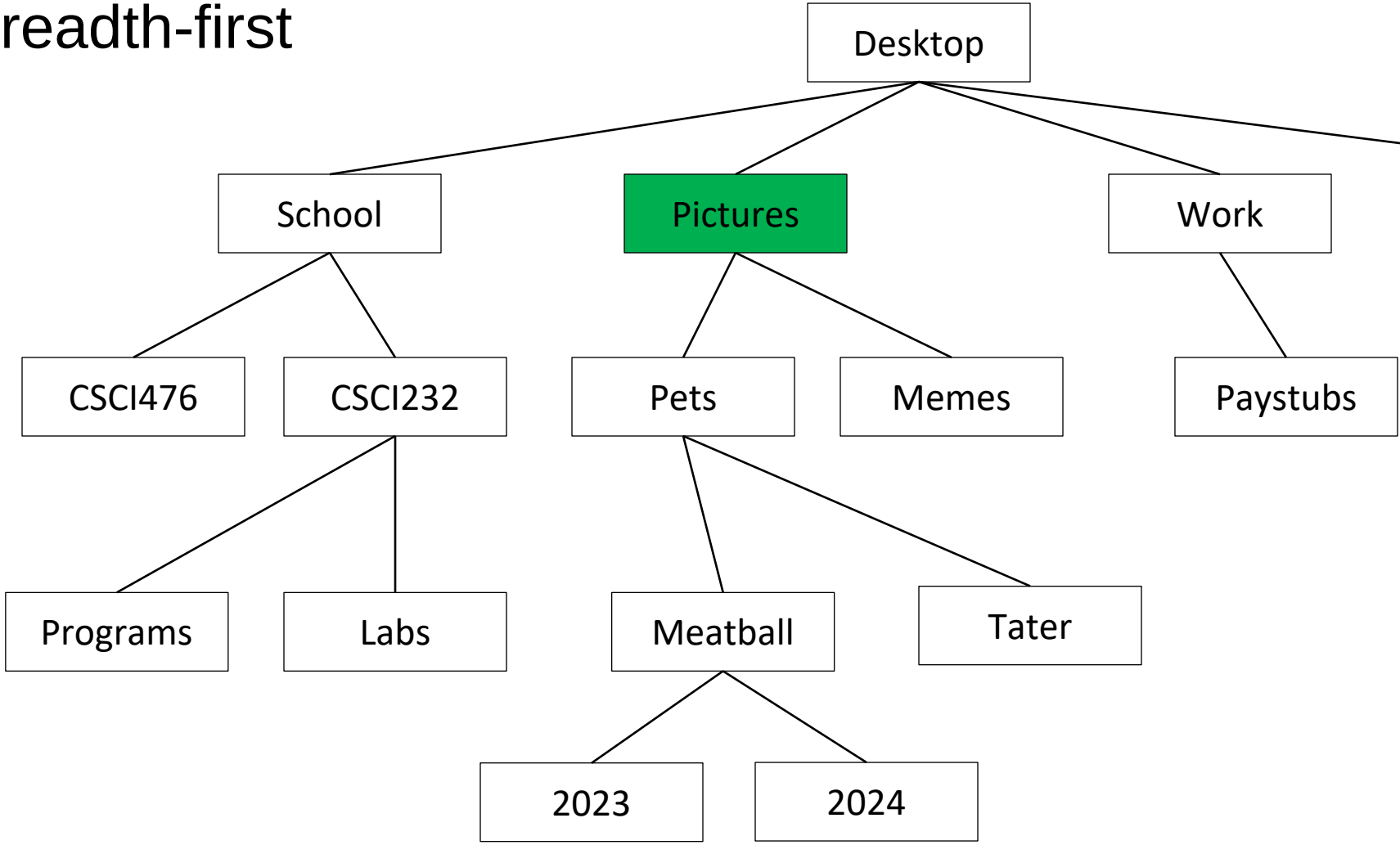

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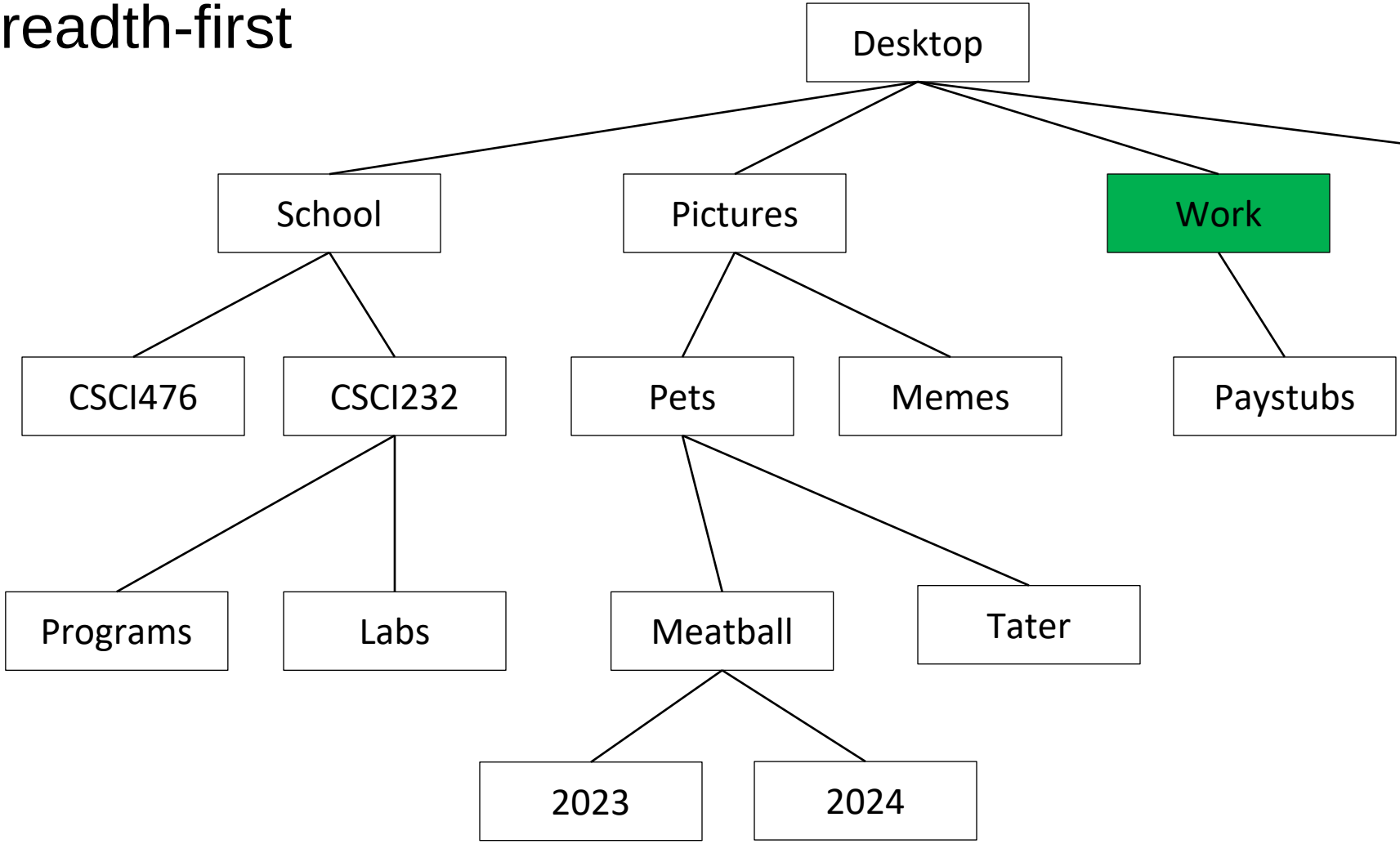

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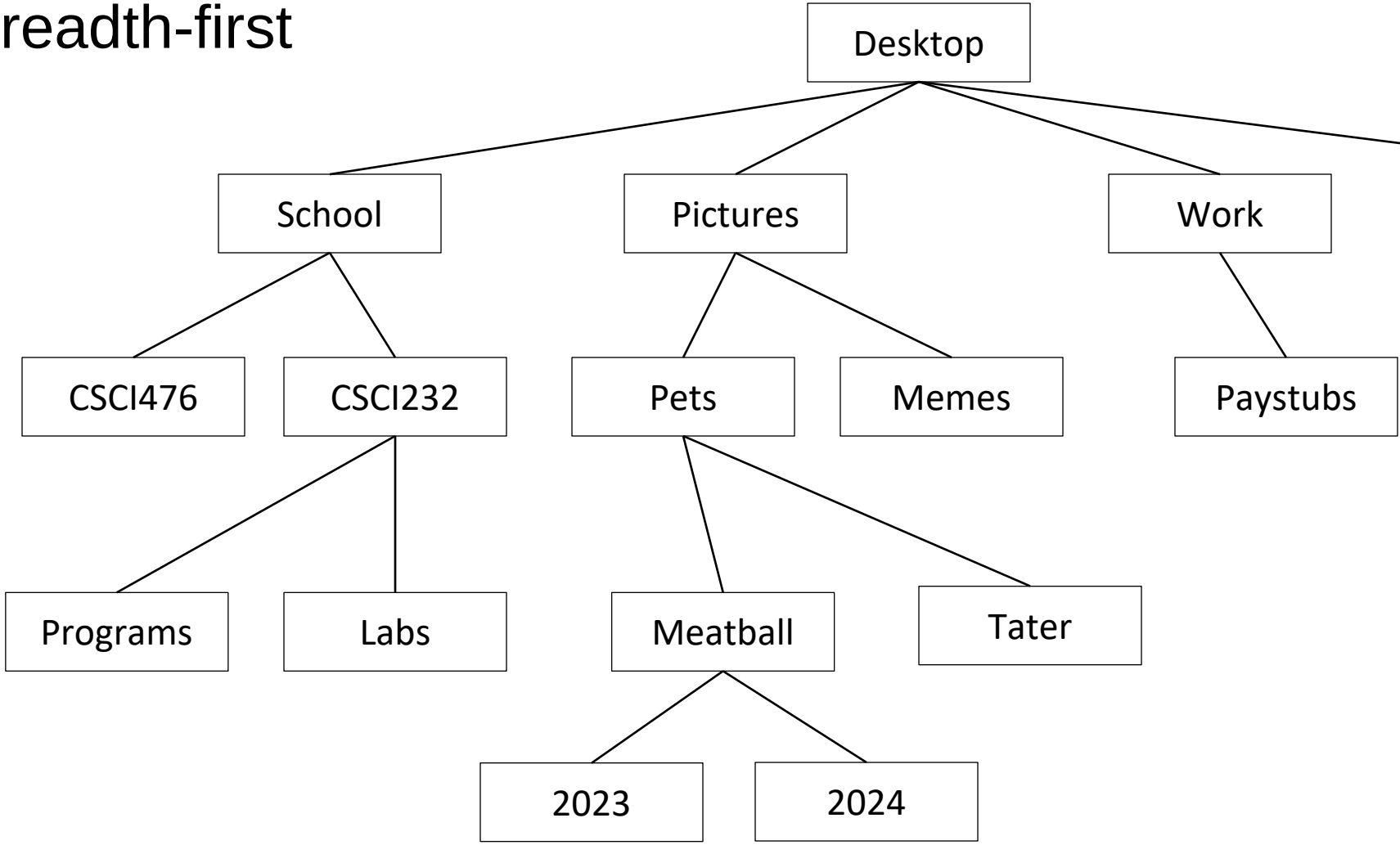

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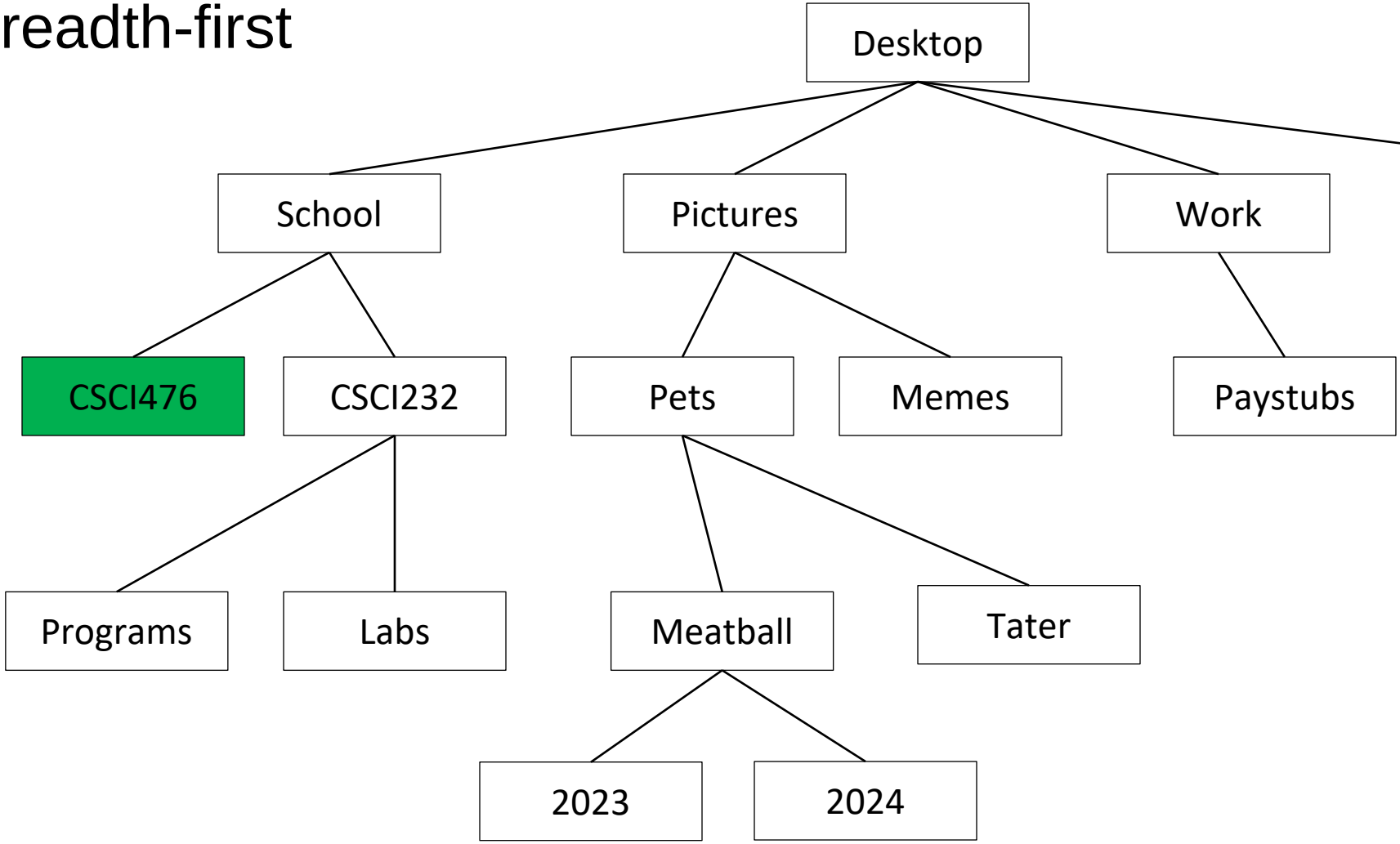

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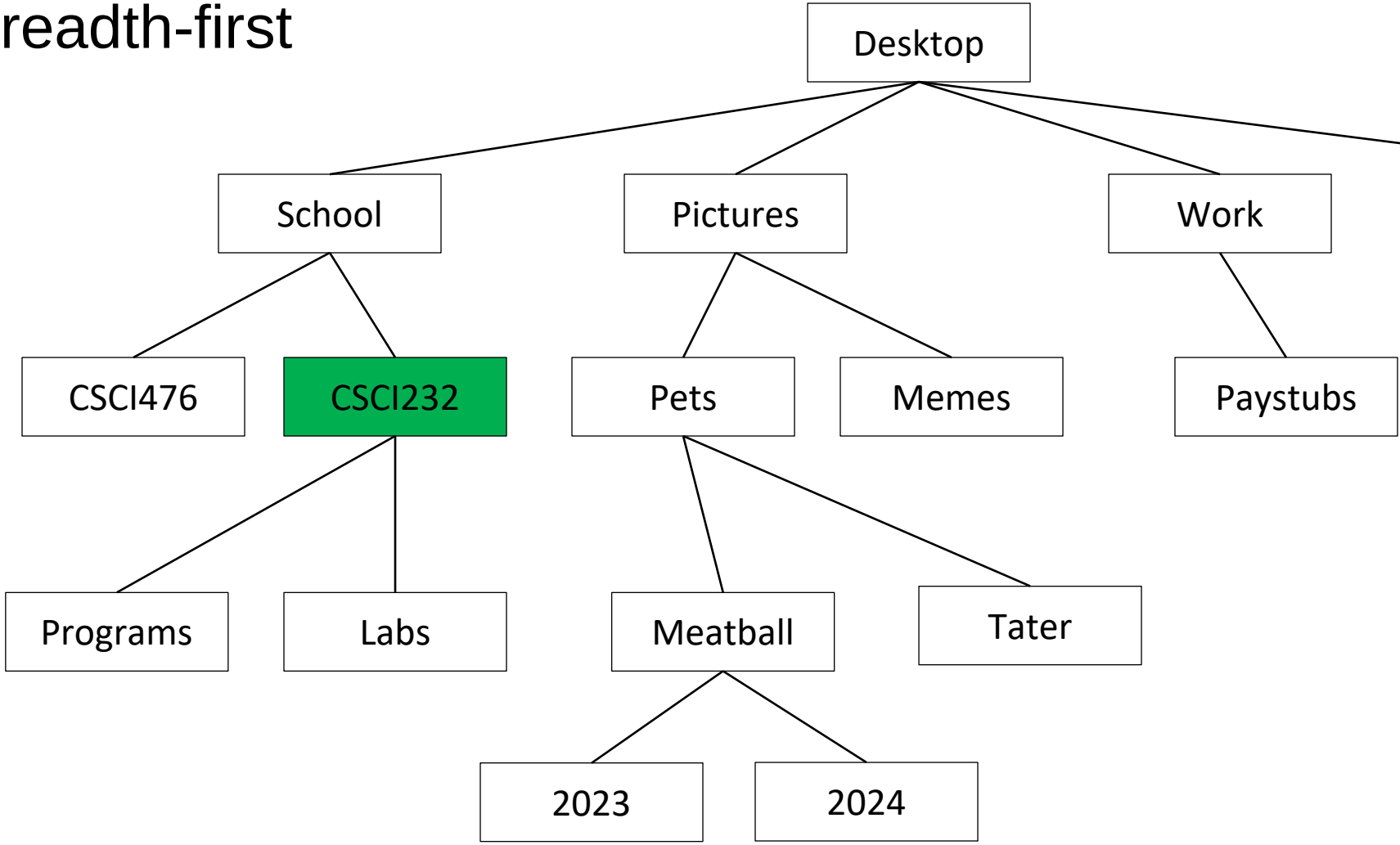

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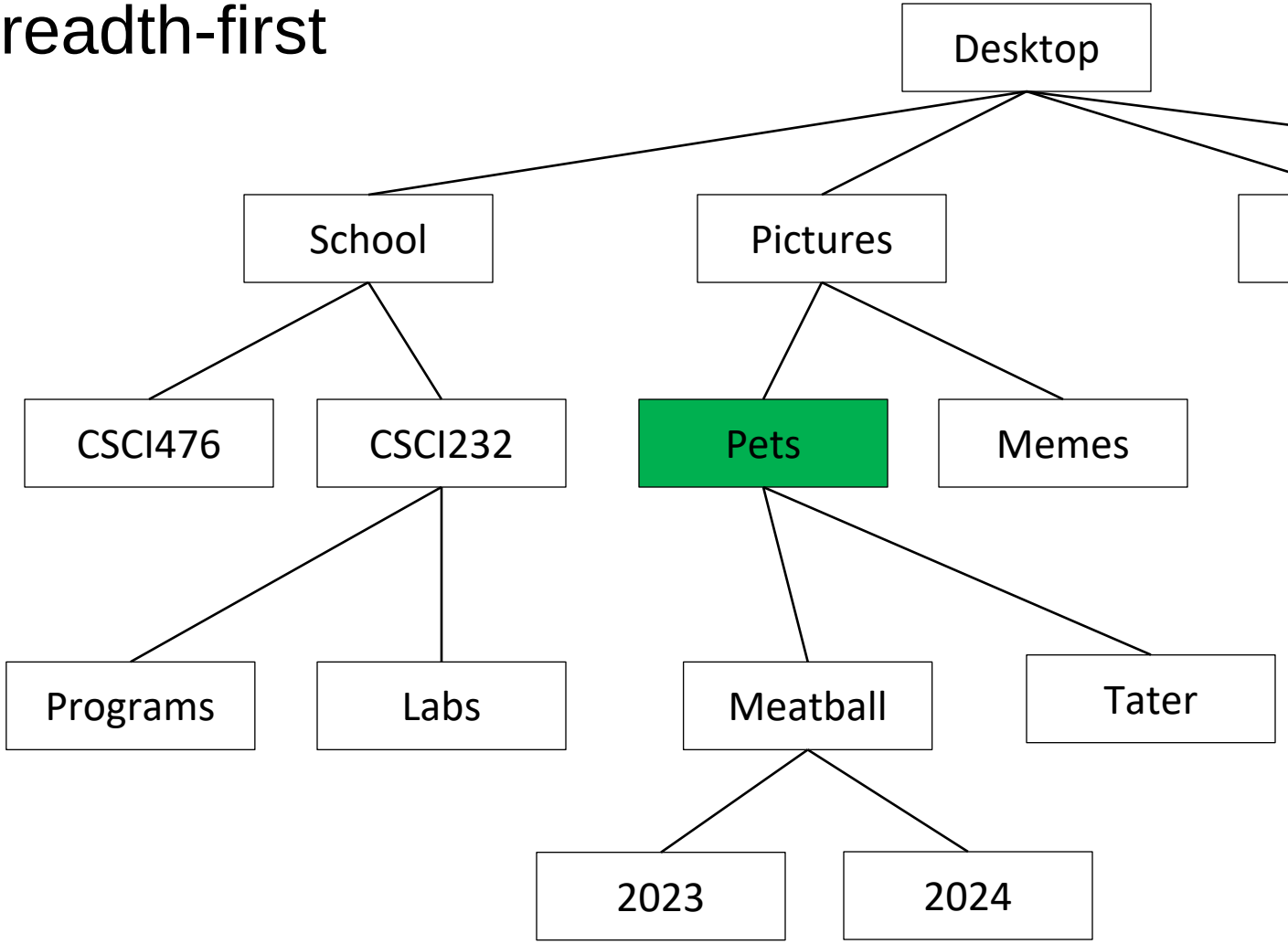

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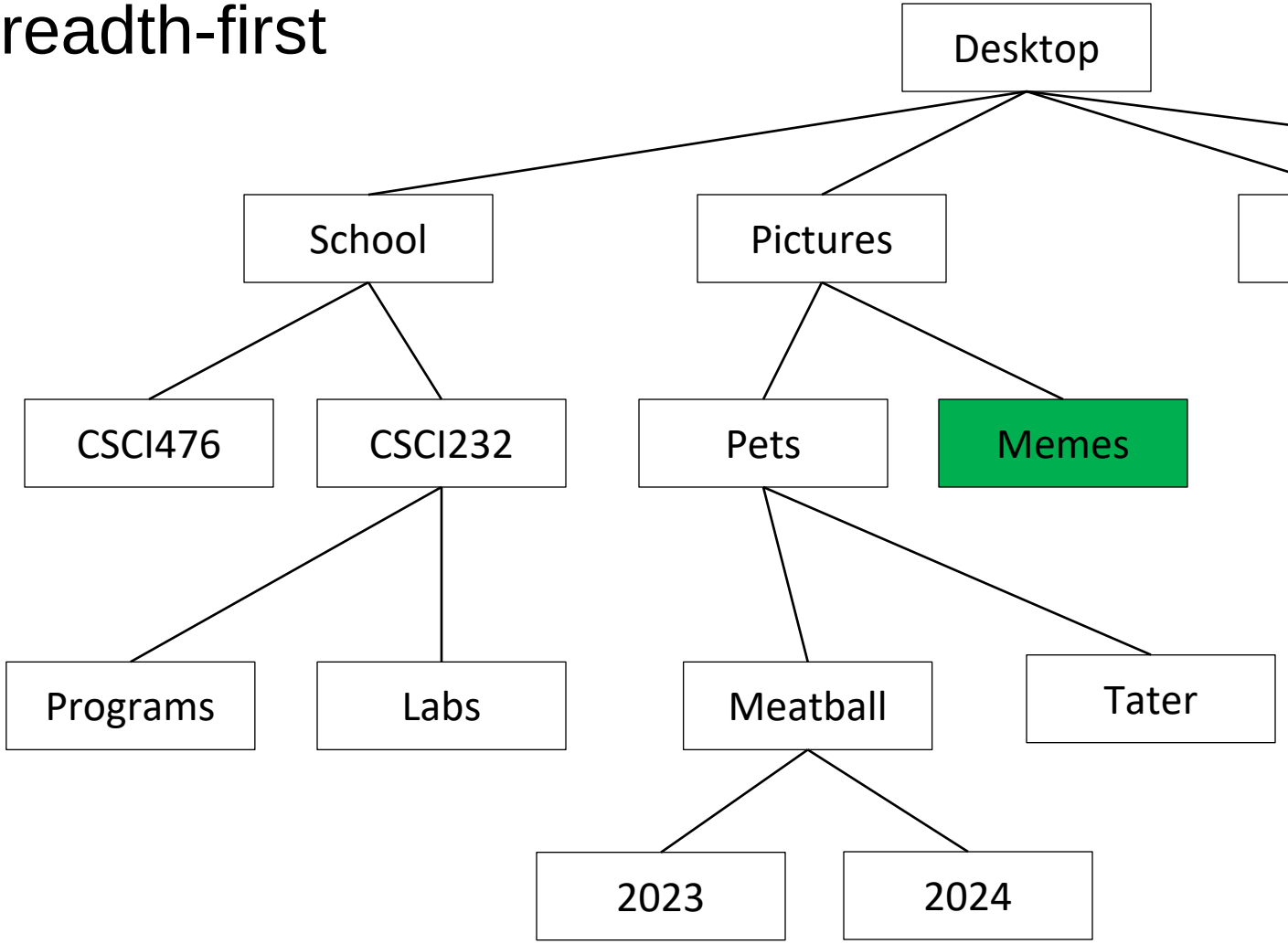

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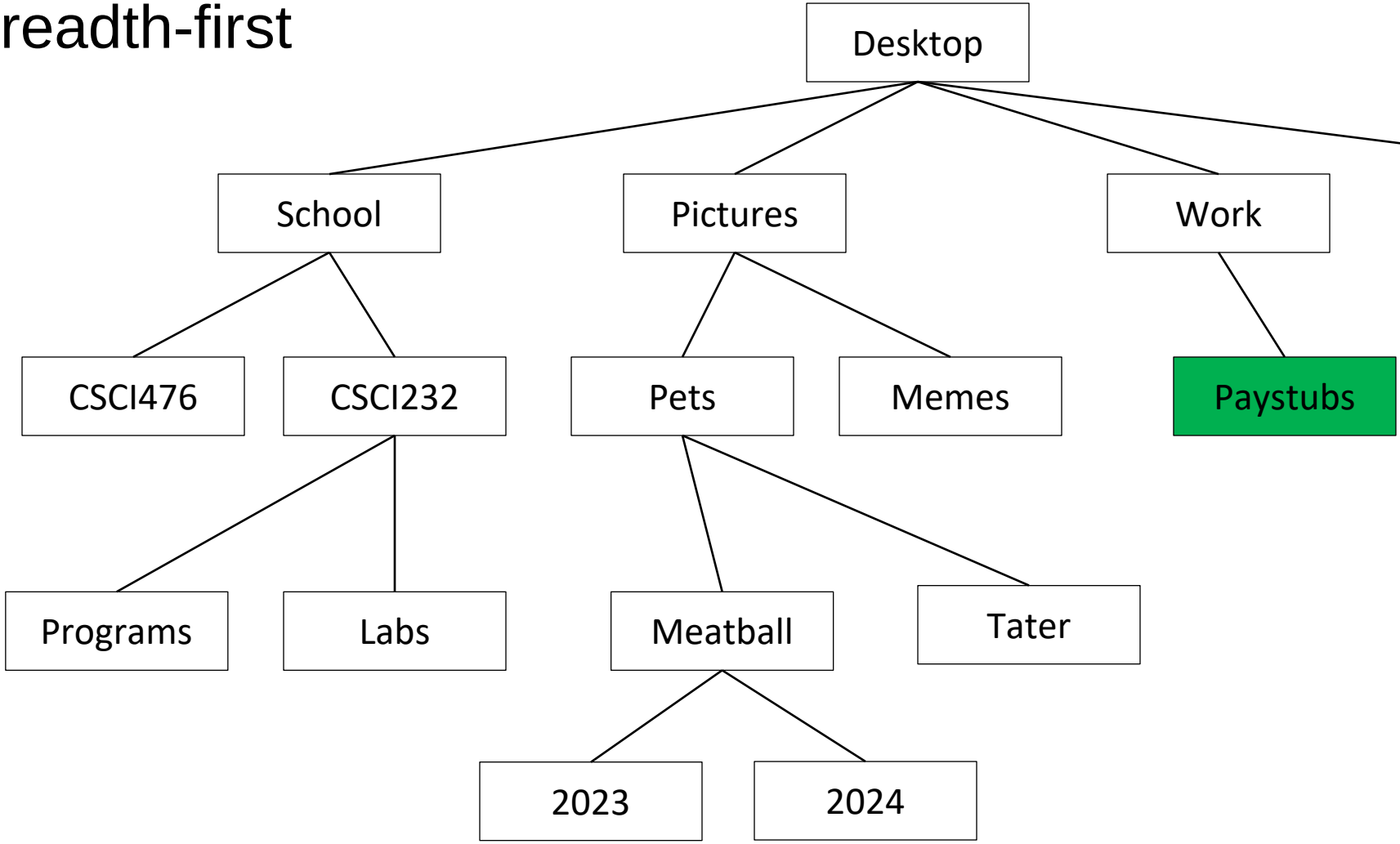

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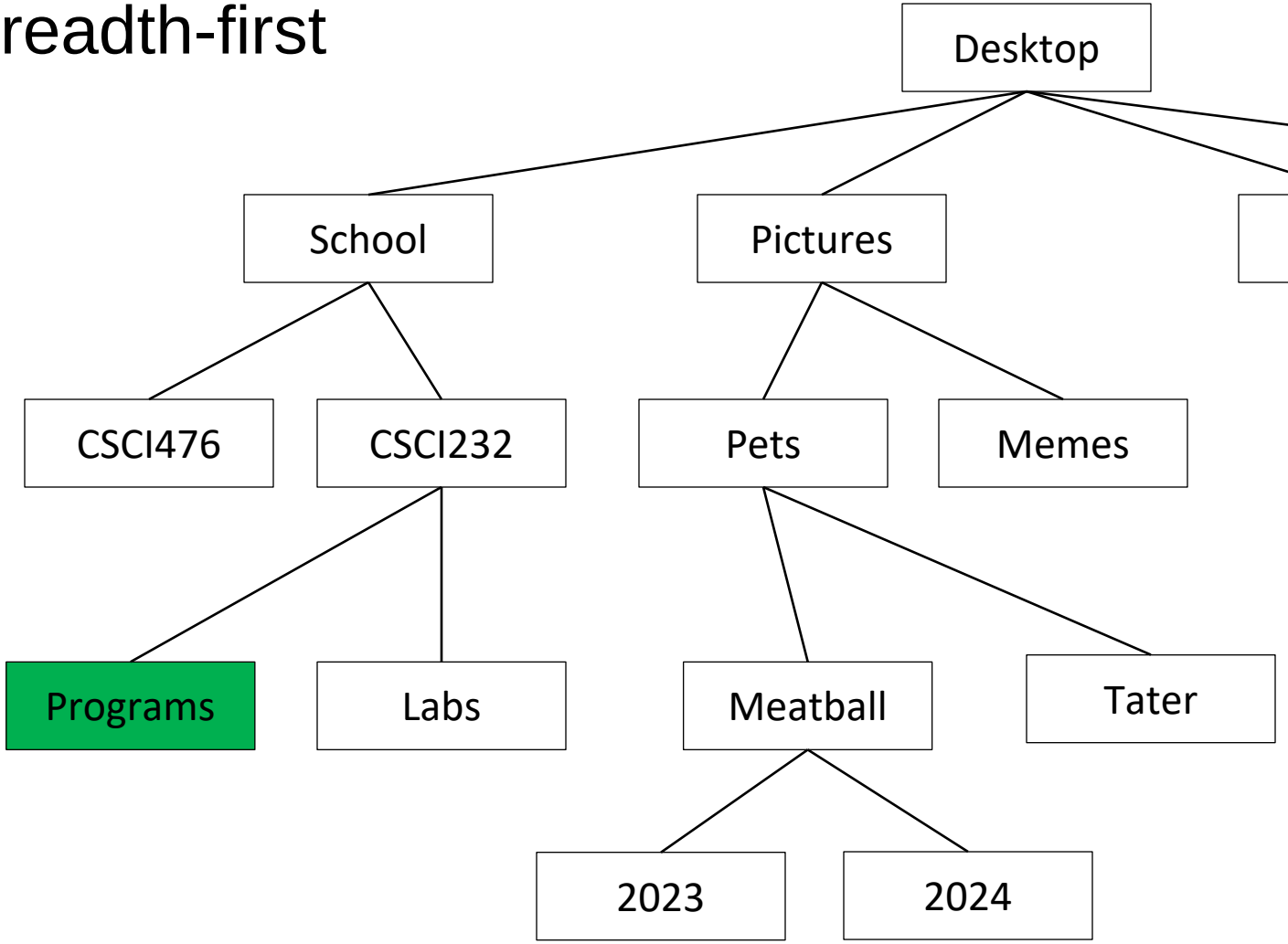

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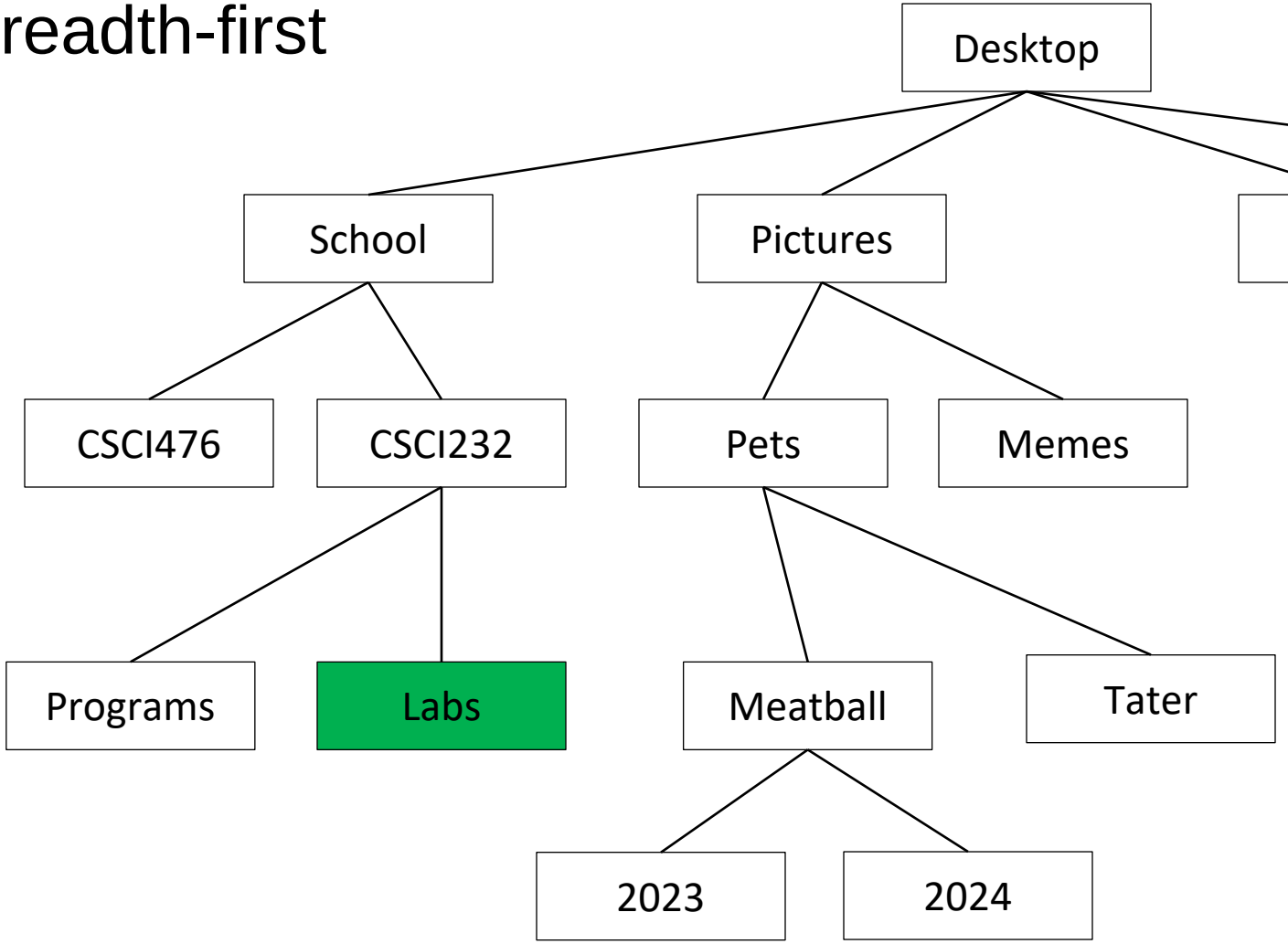

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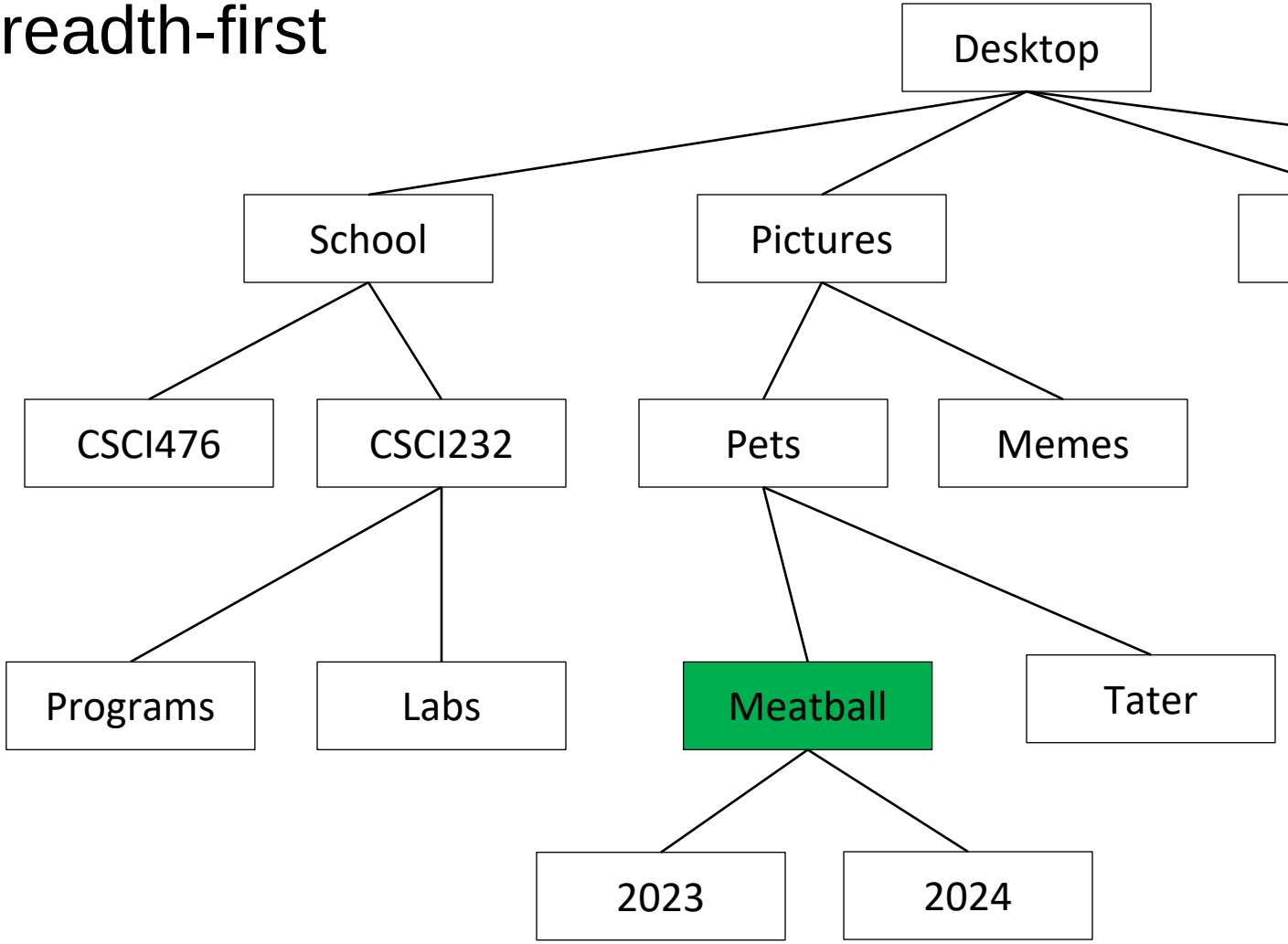

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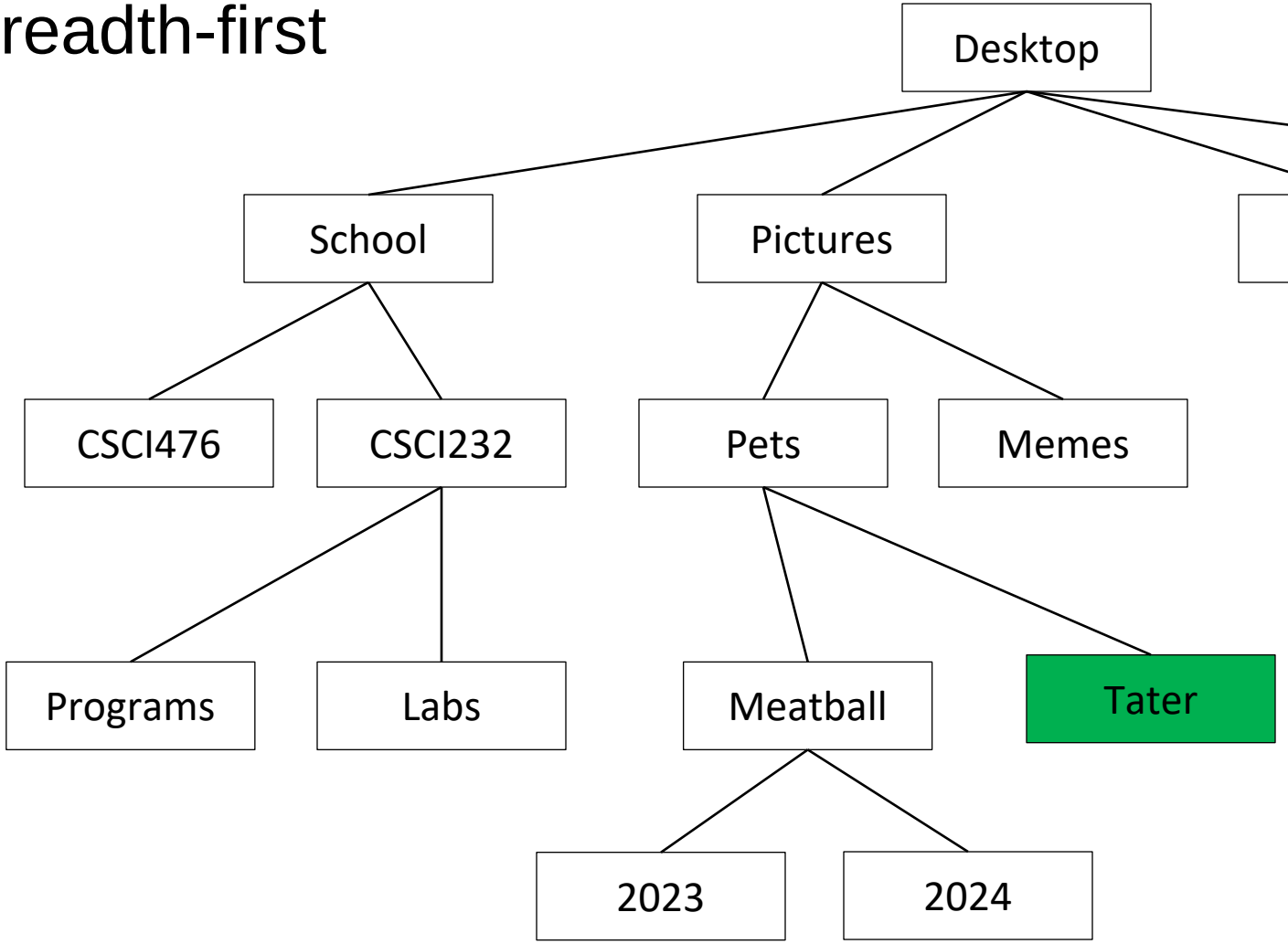

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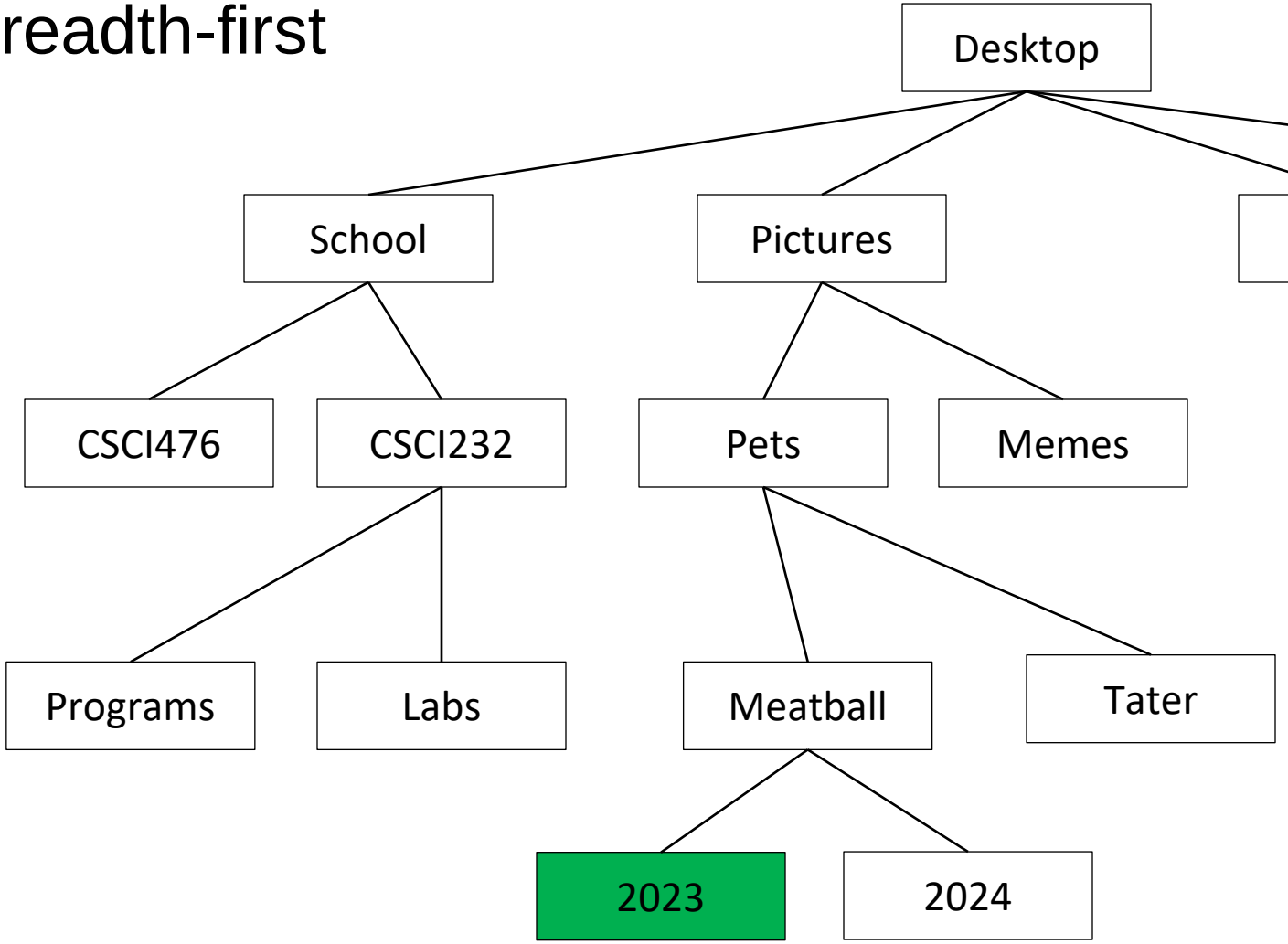

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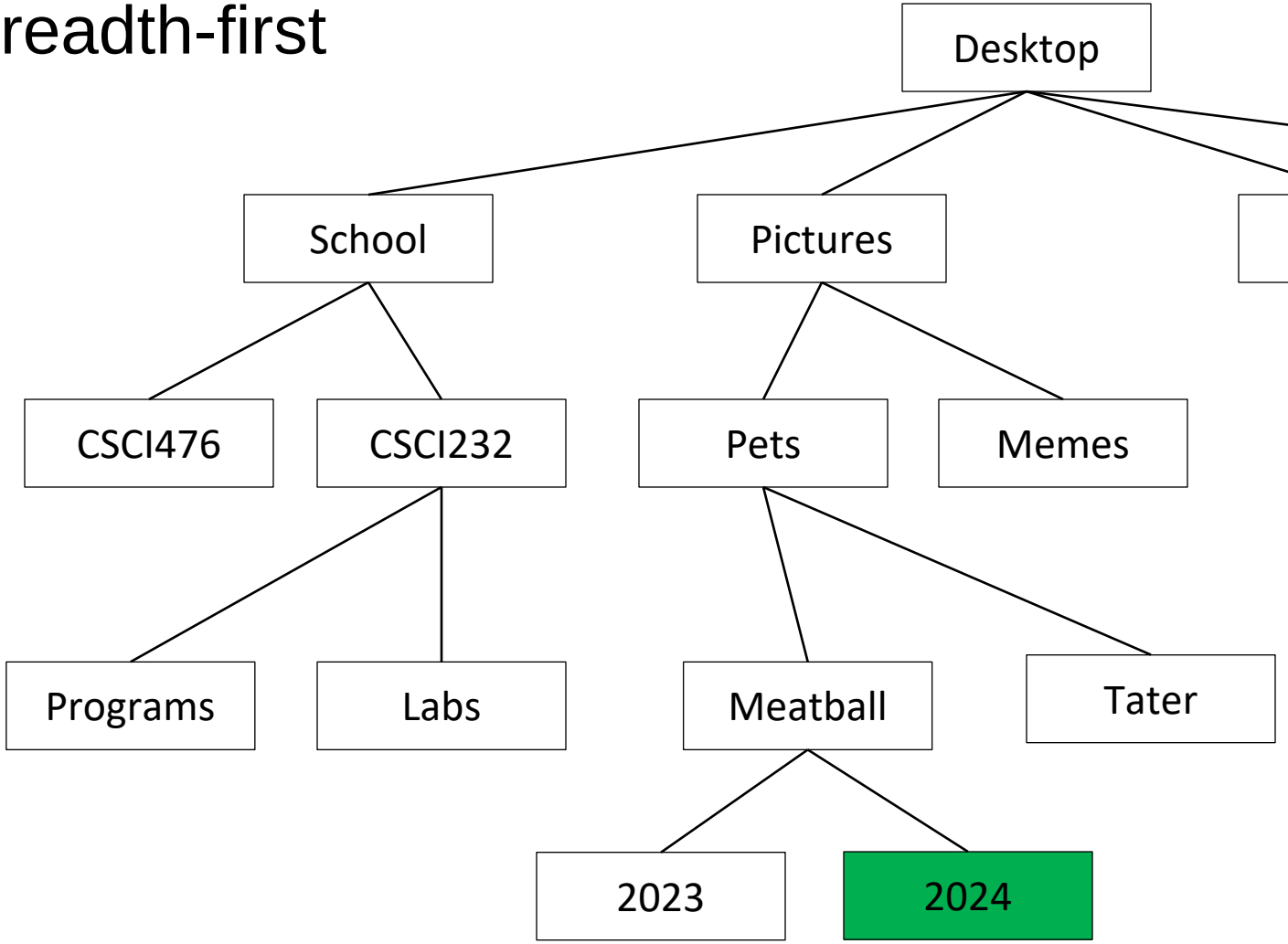

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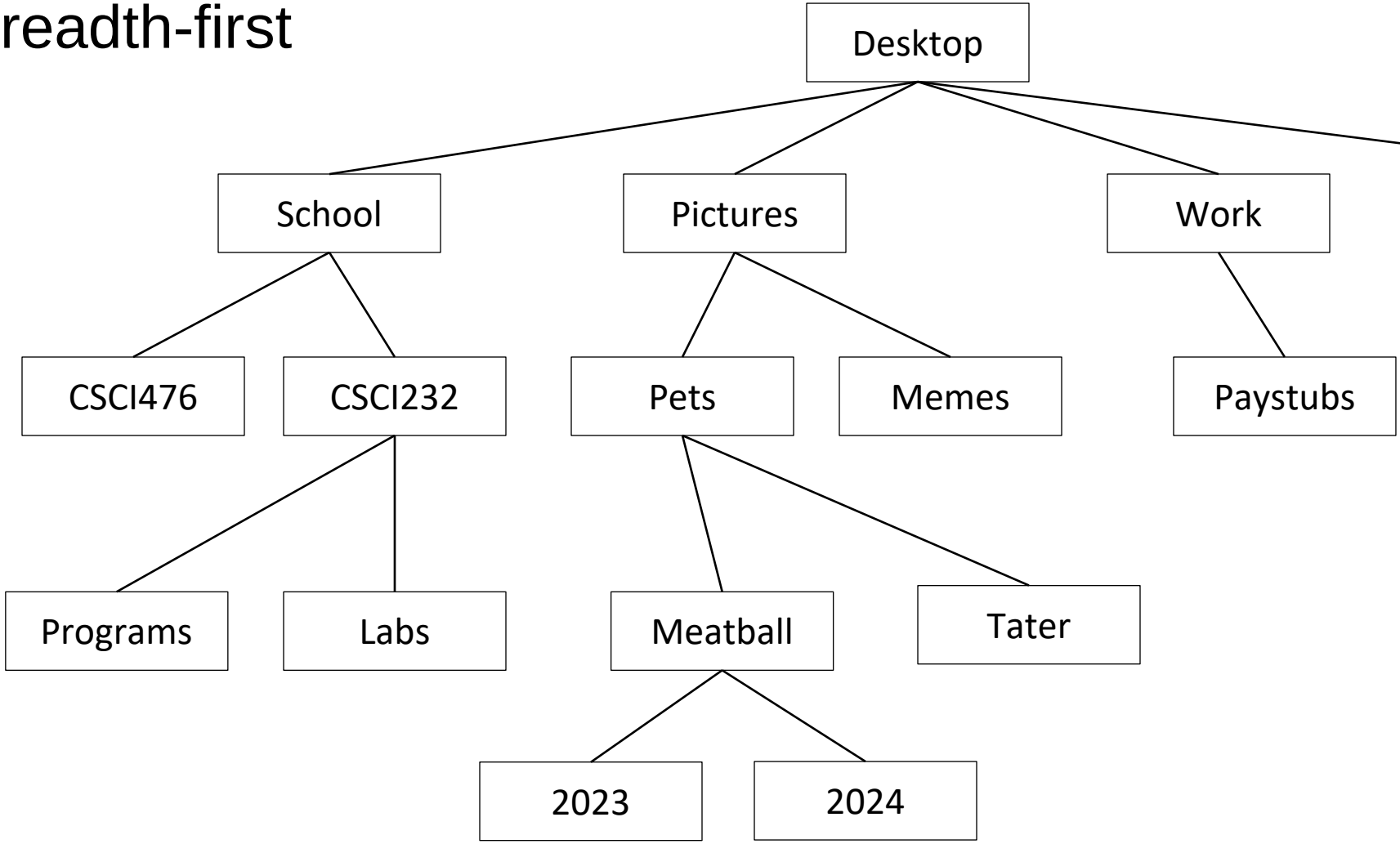

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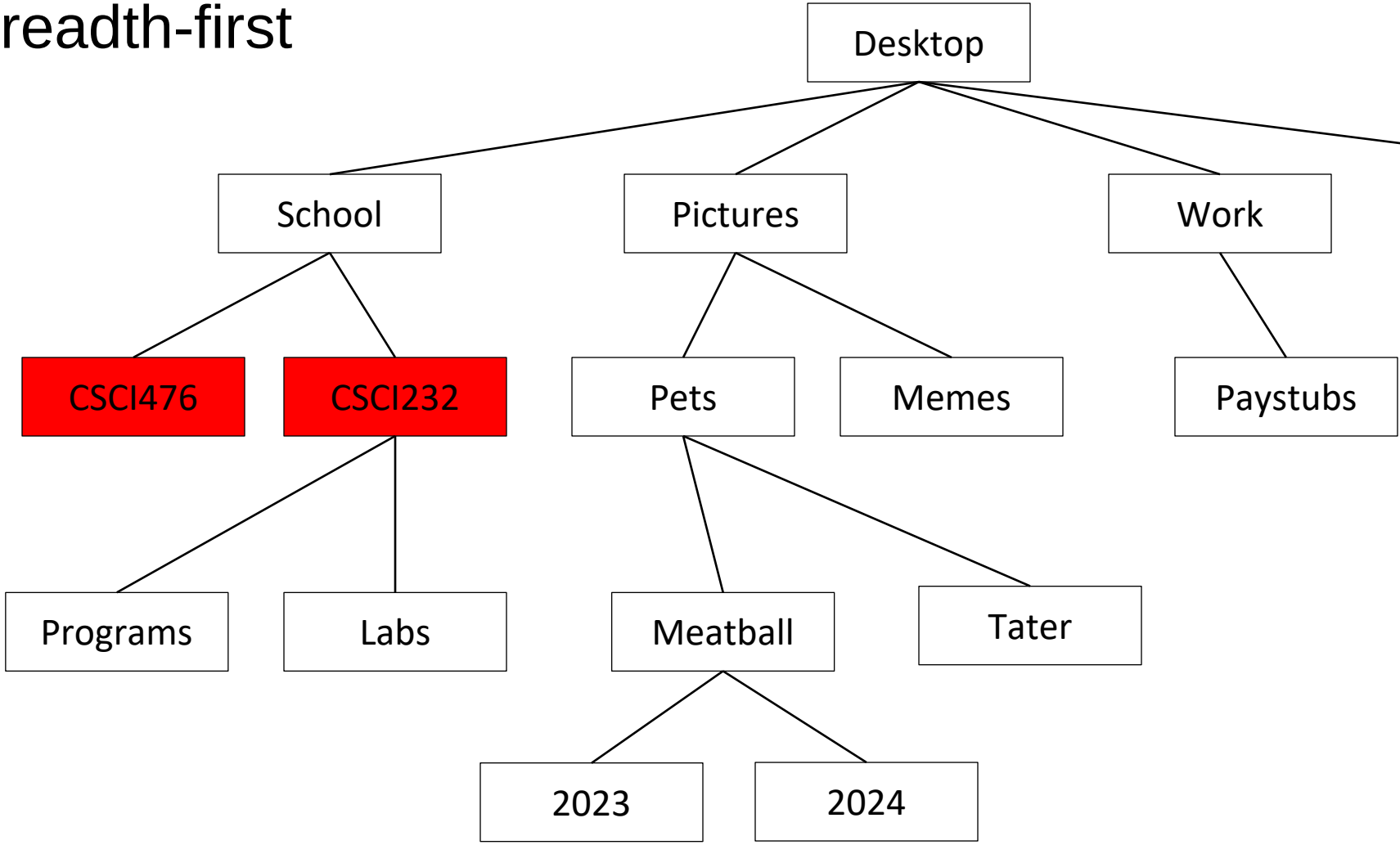

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How do we know that the **children of School** are the nodes to visit after **Documents**?

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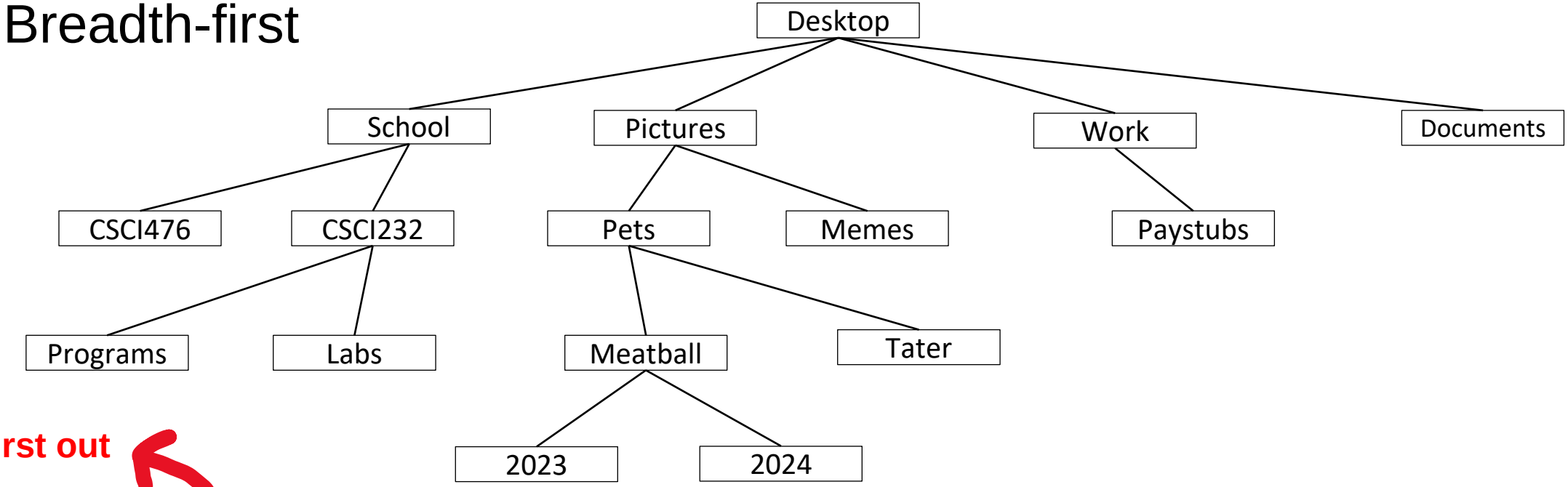

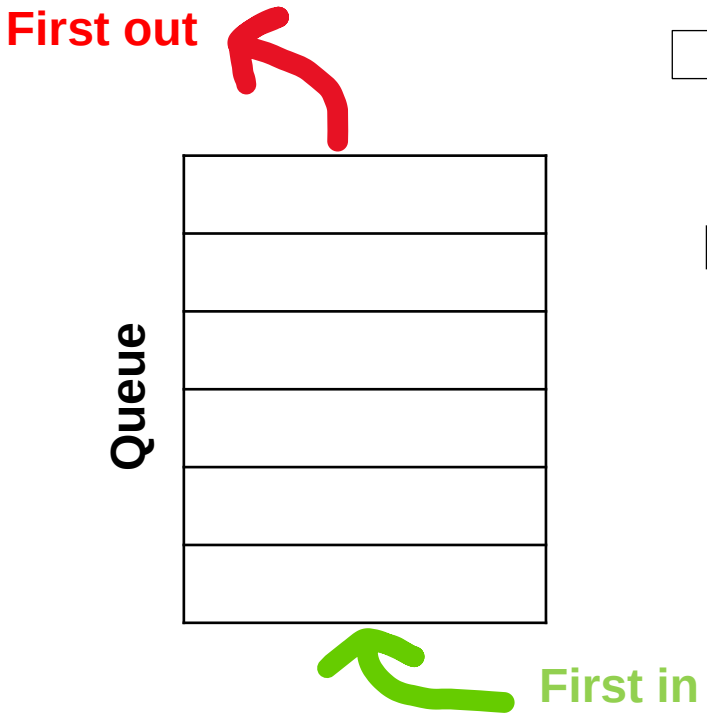

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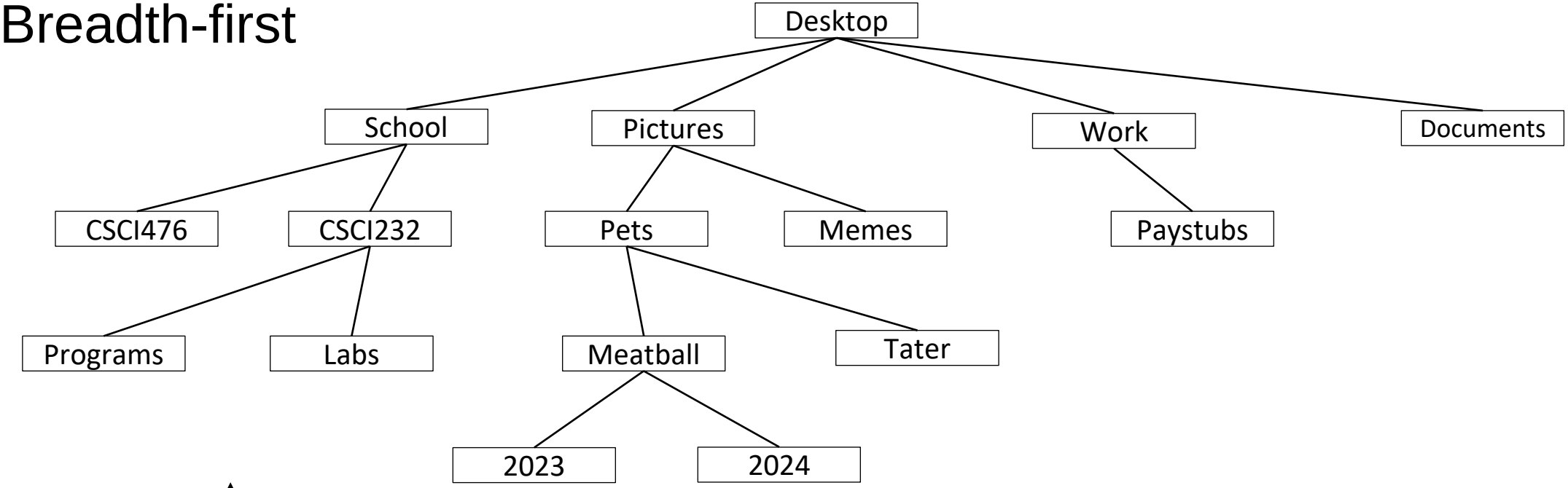
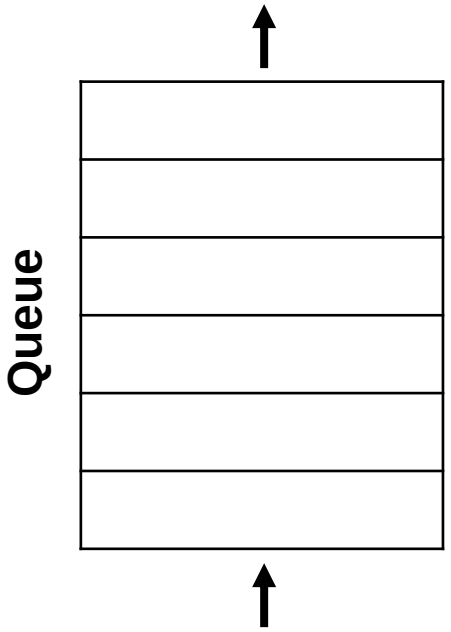
What if we use a **Queue** ?

Breadth-first





Every time we “visit” a node we:

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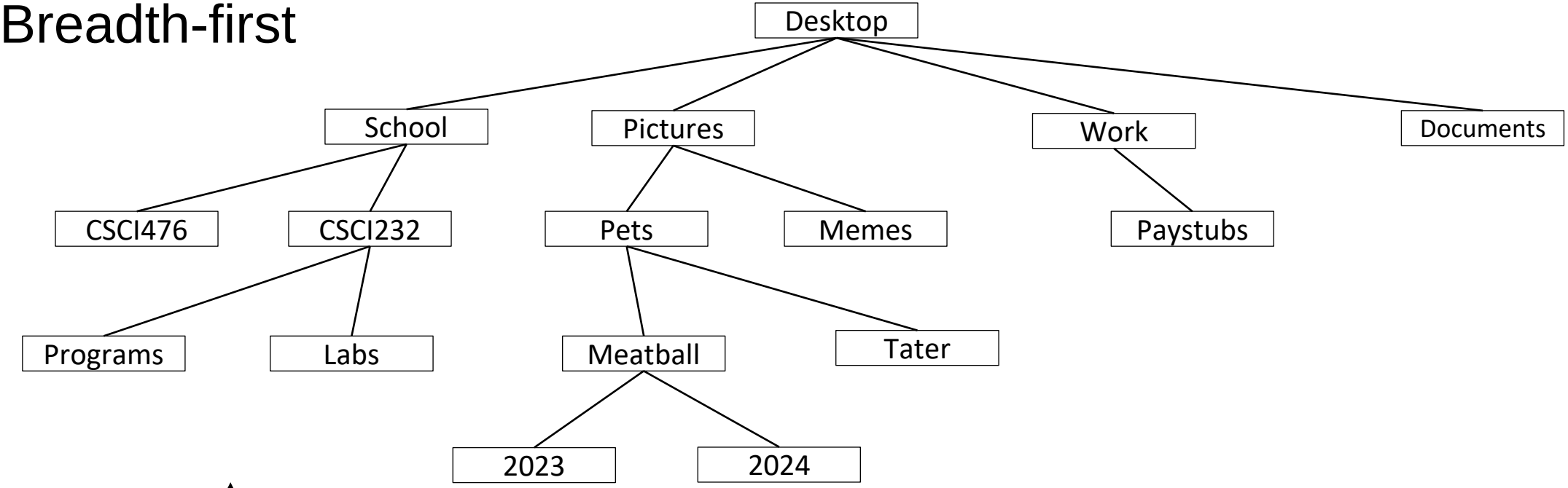

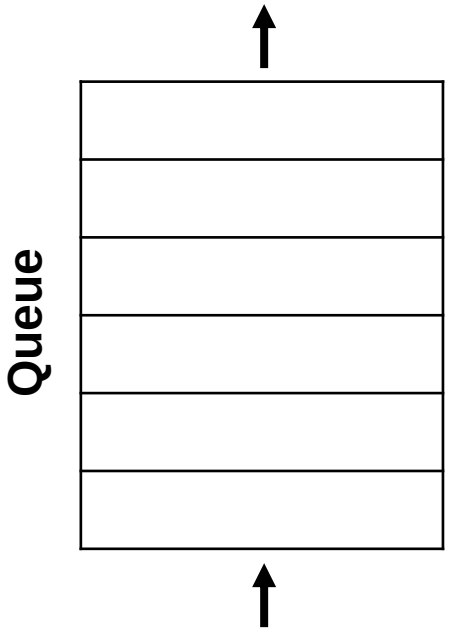

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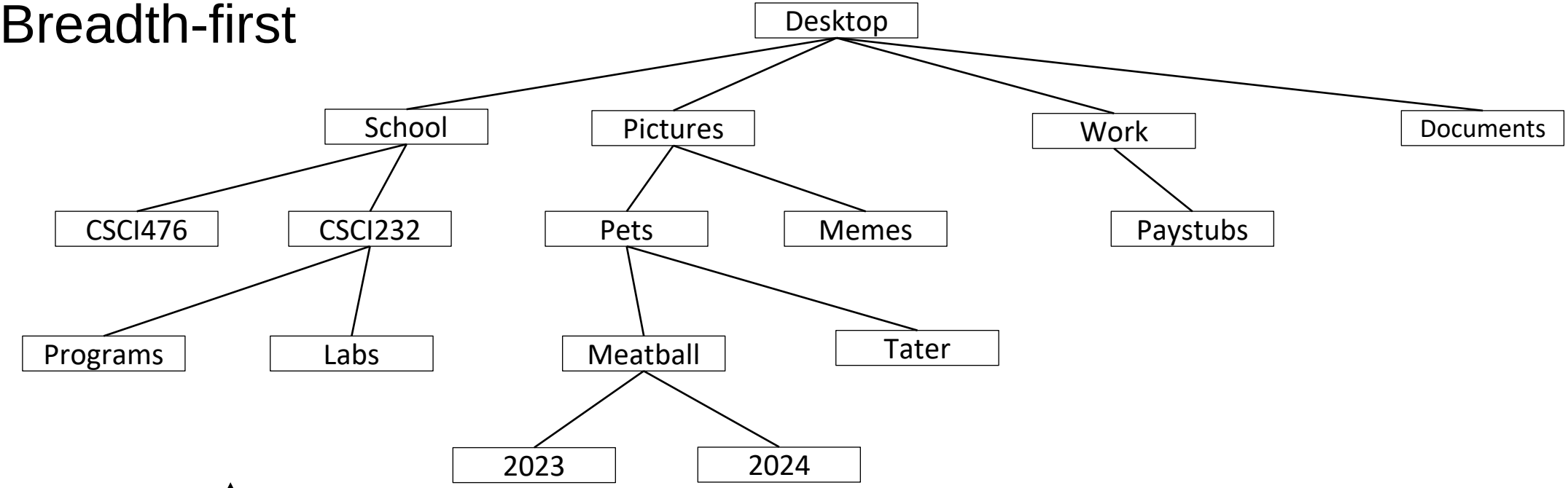

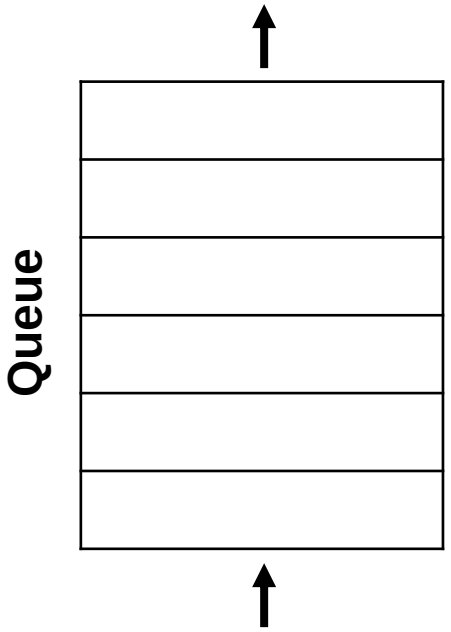

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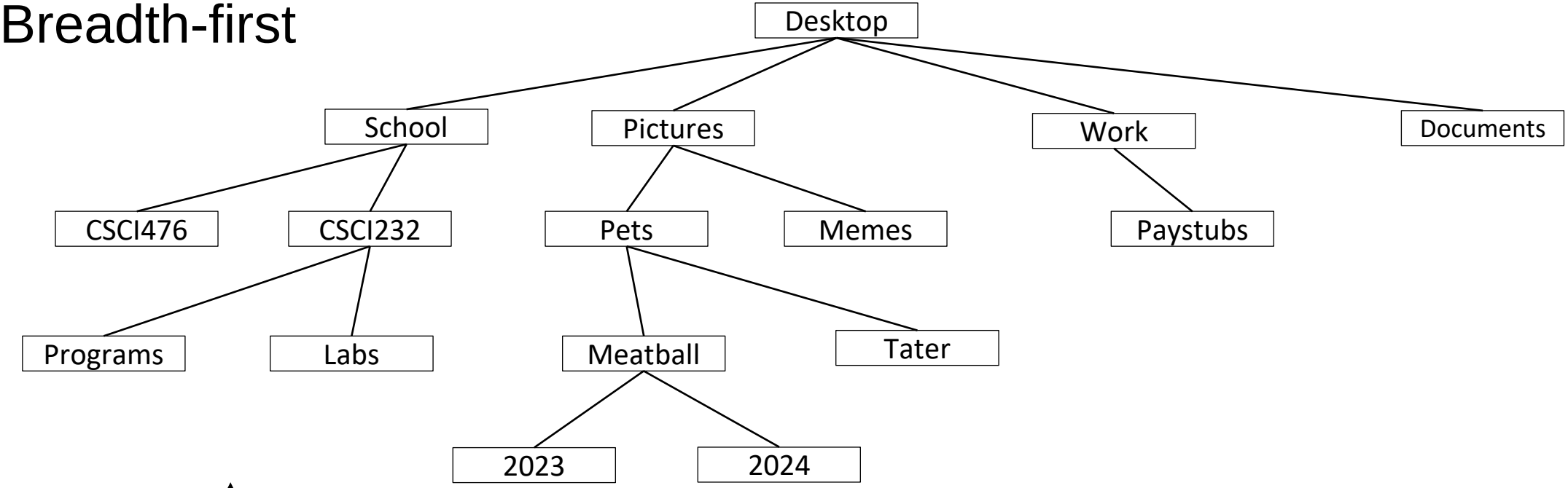

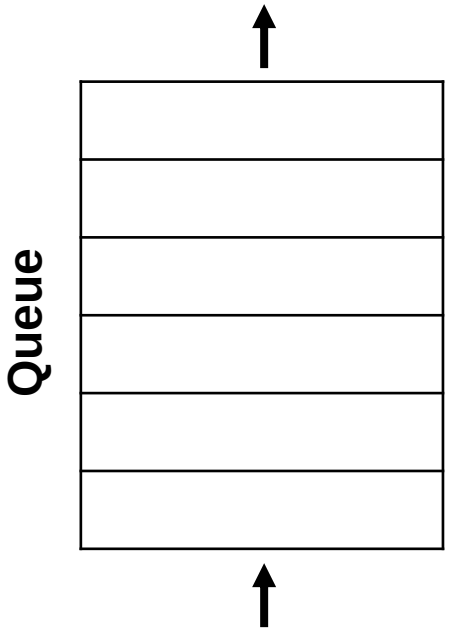

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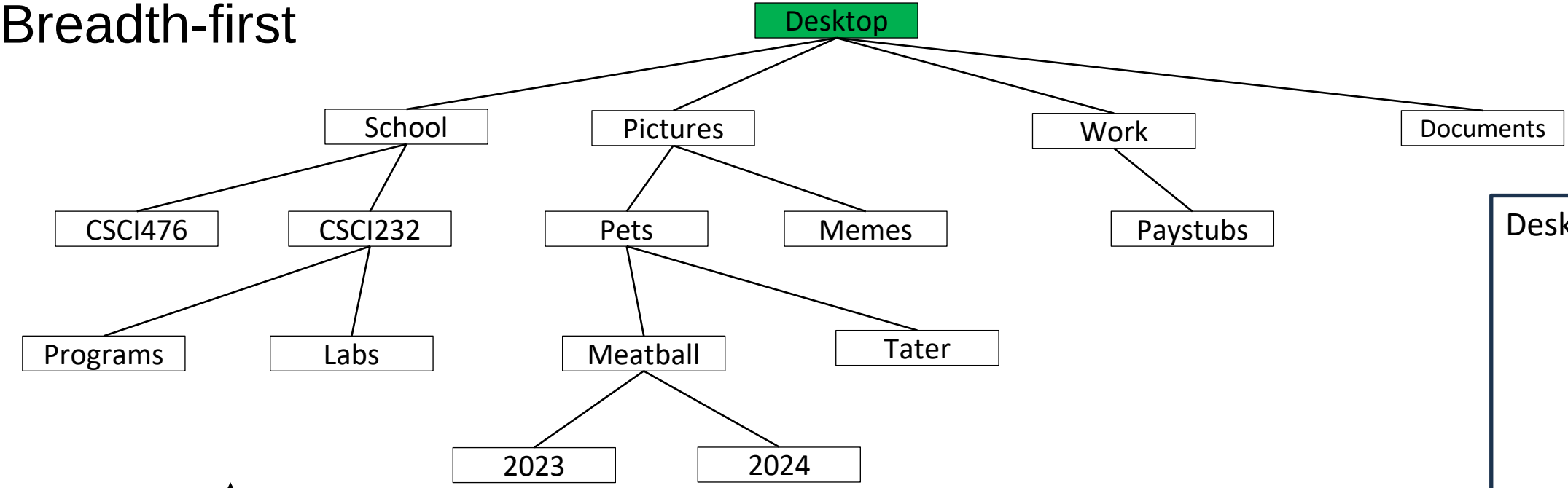
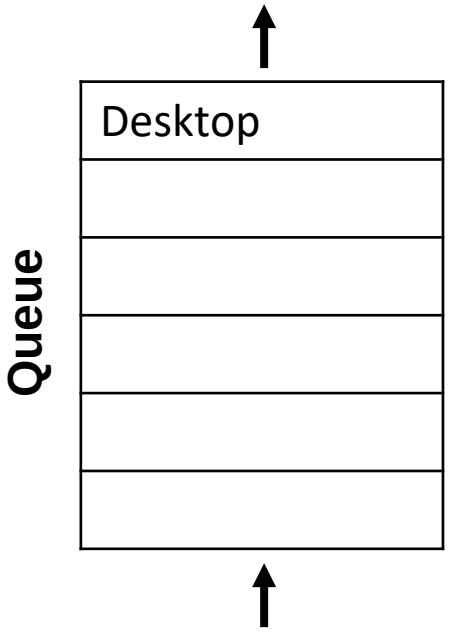


Output

Desktop



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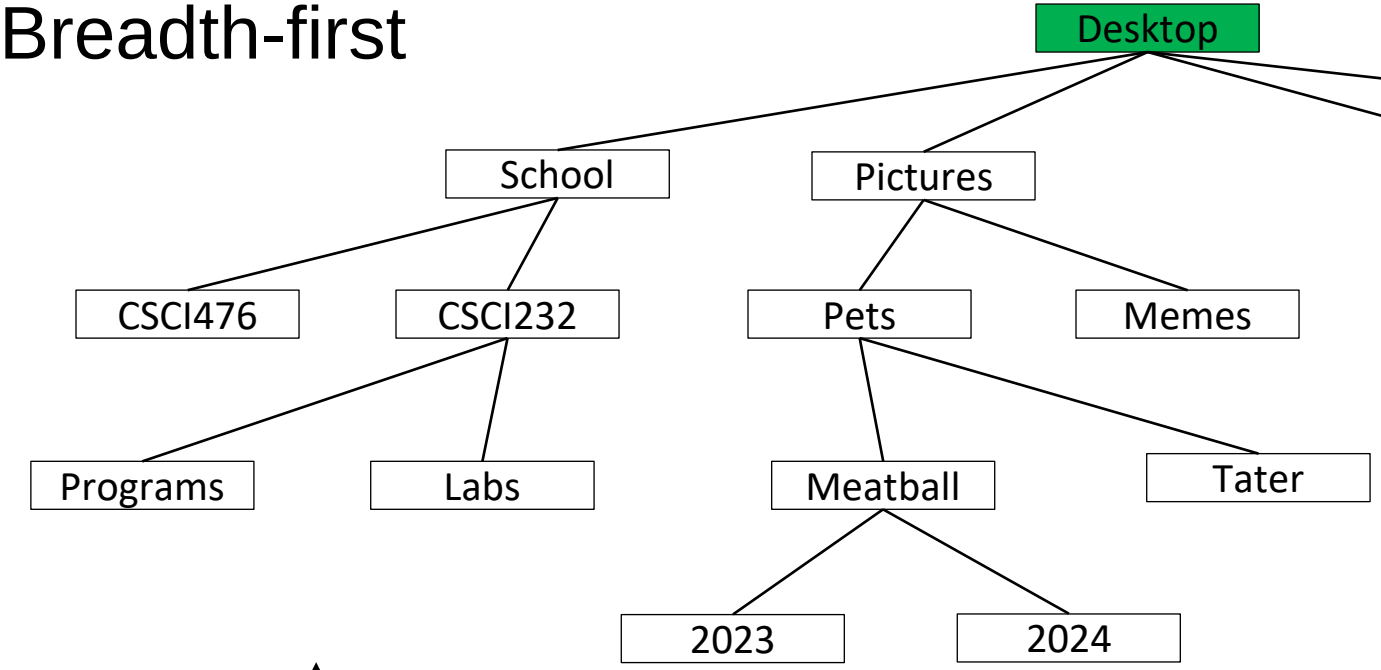

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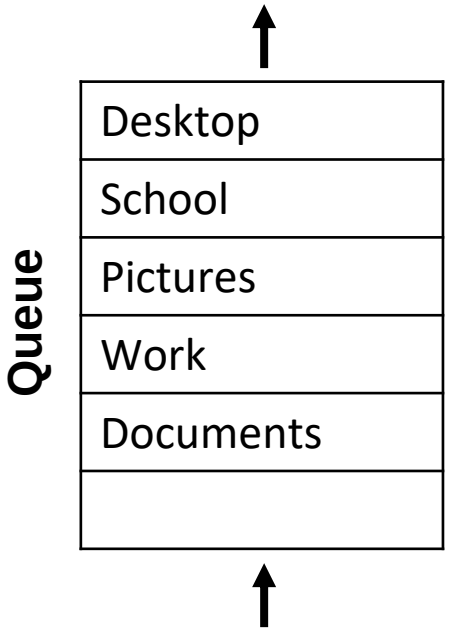

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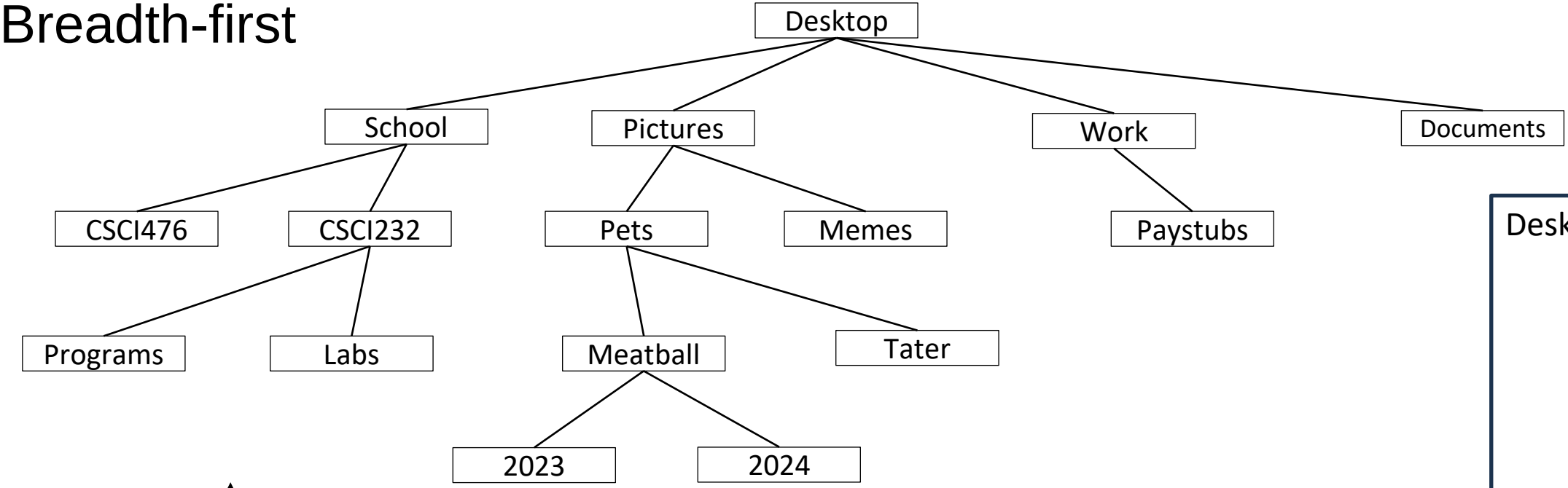

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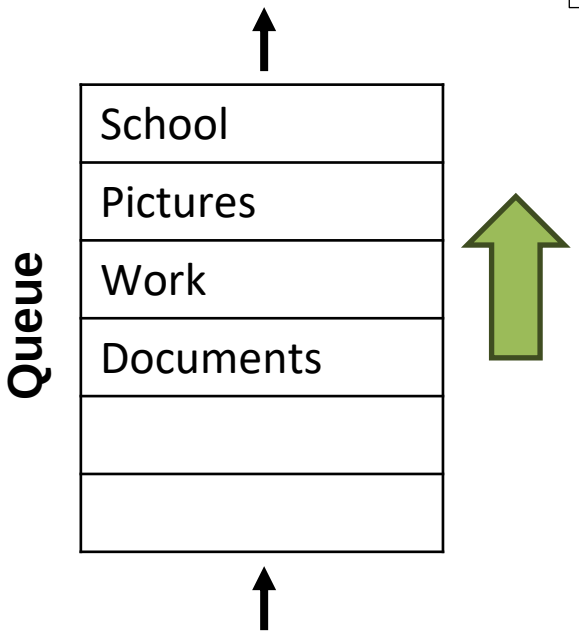

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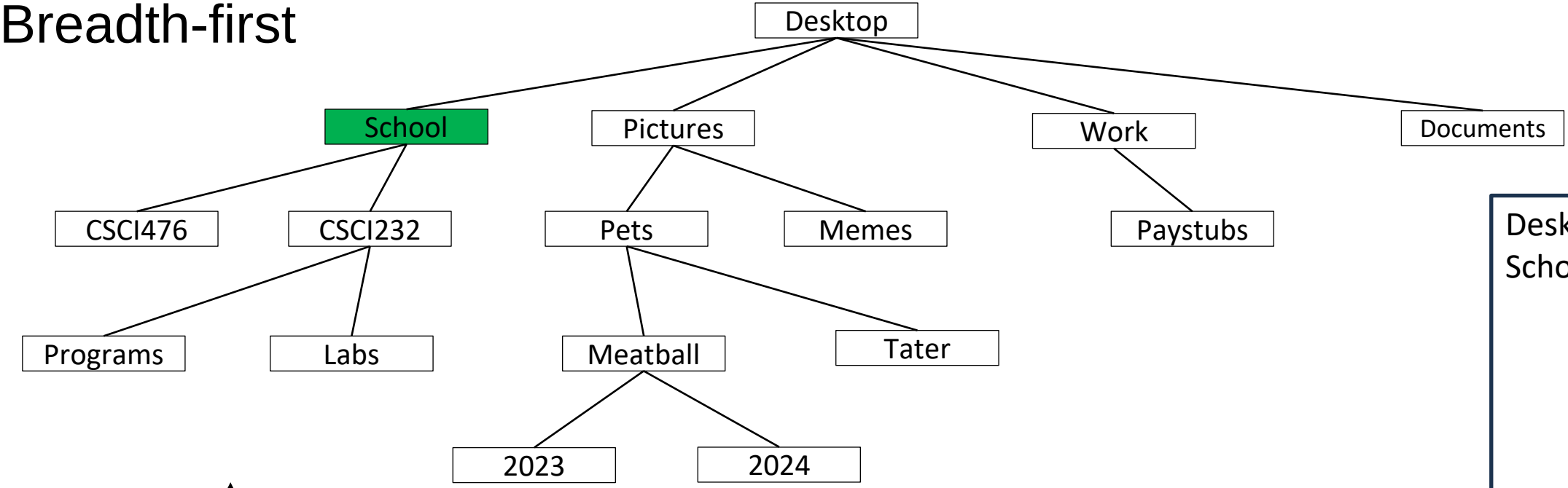

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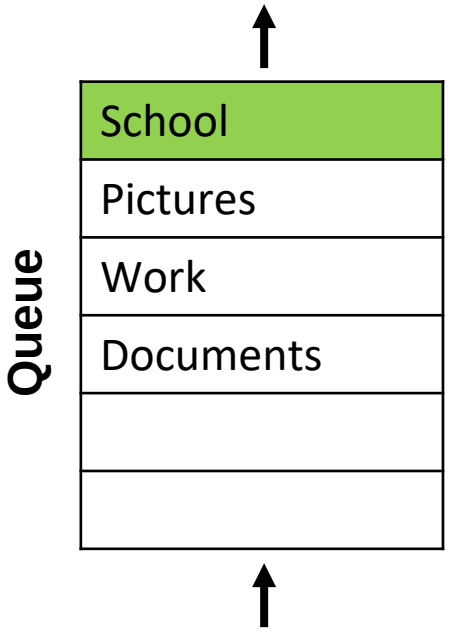

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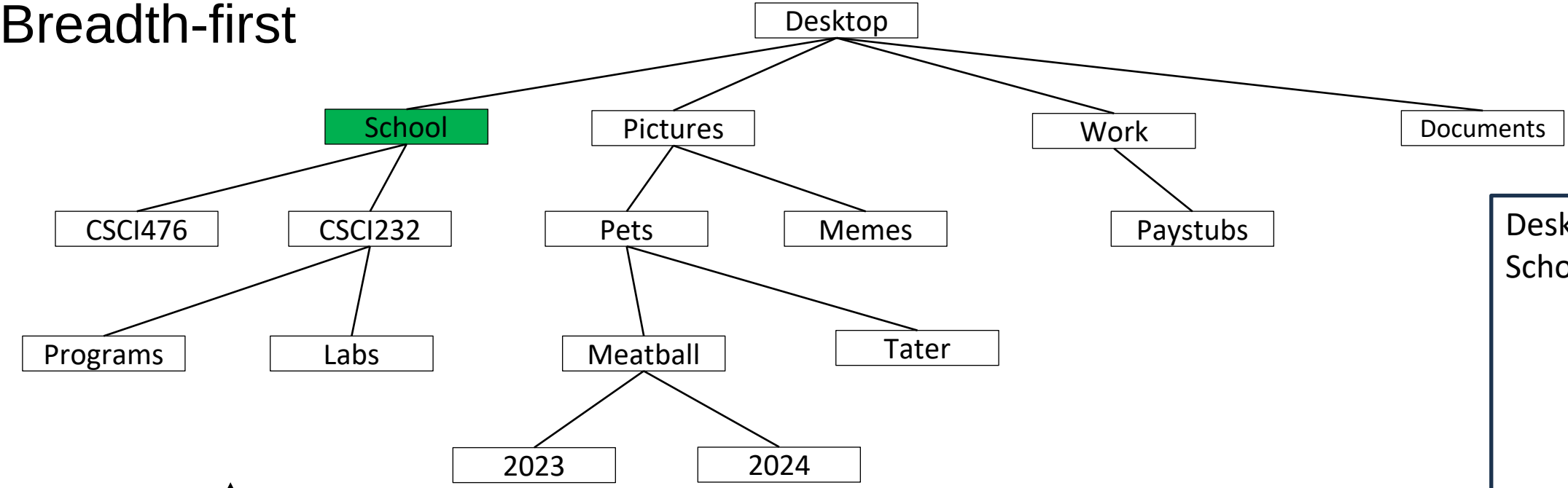

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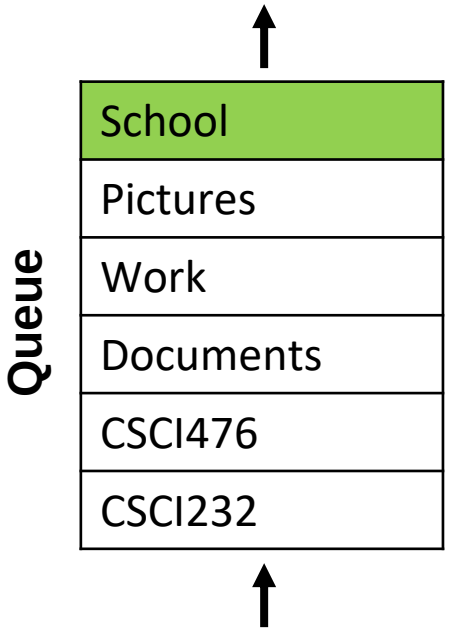

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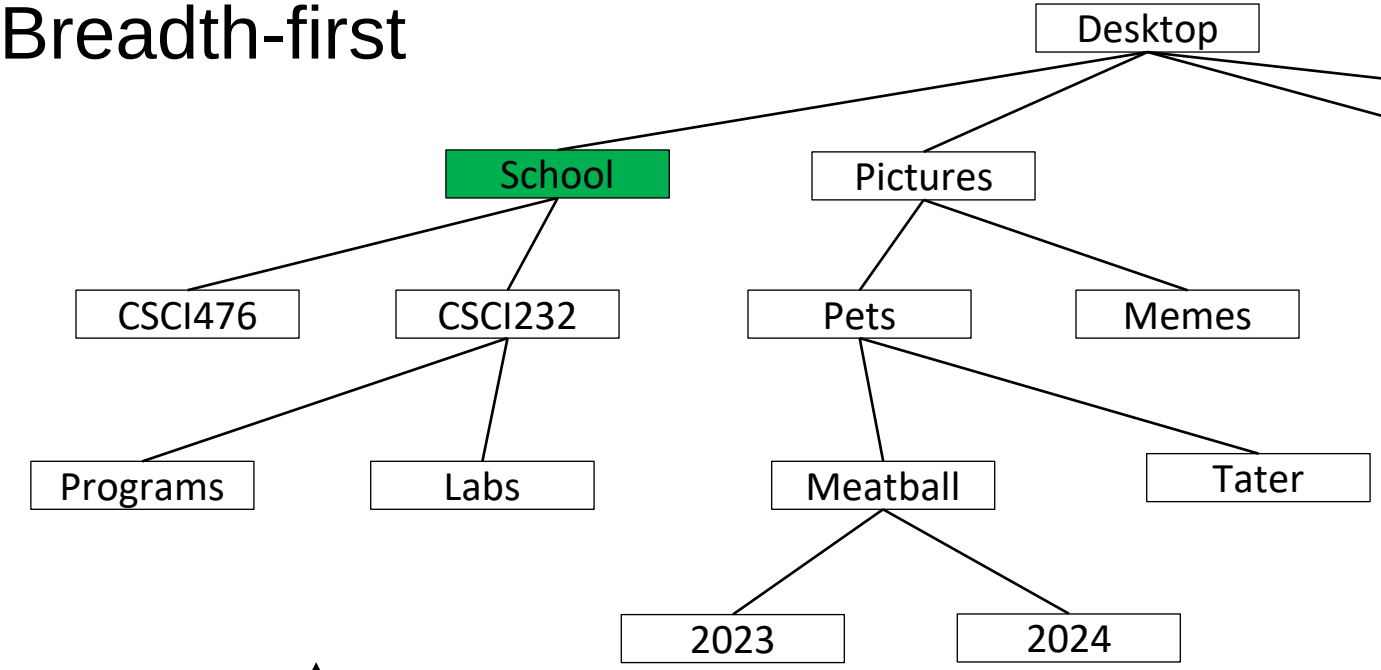

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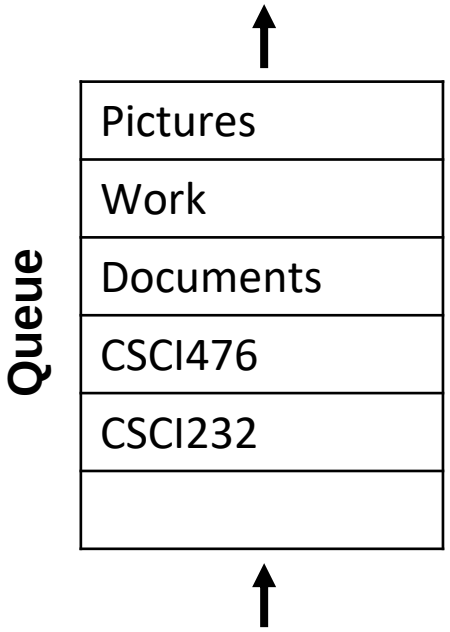

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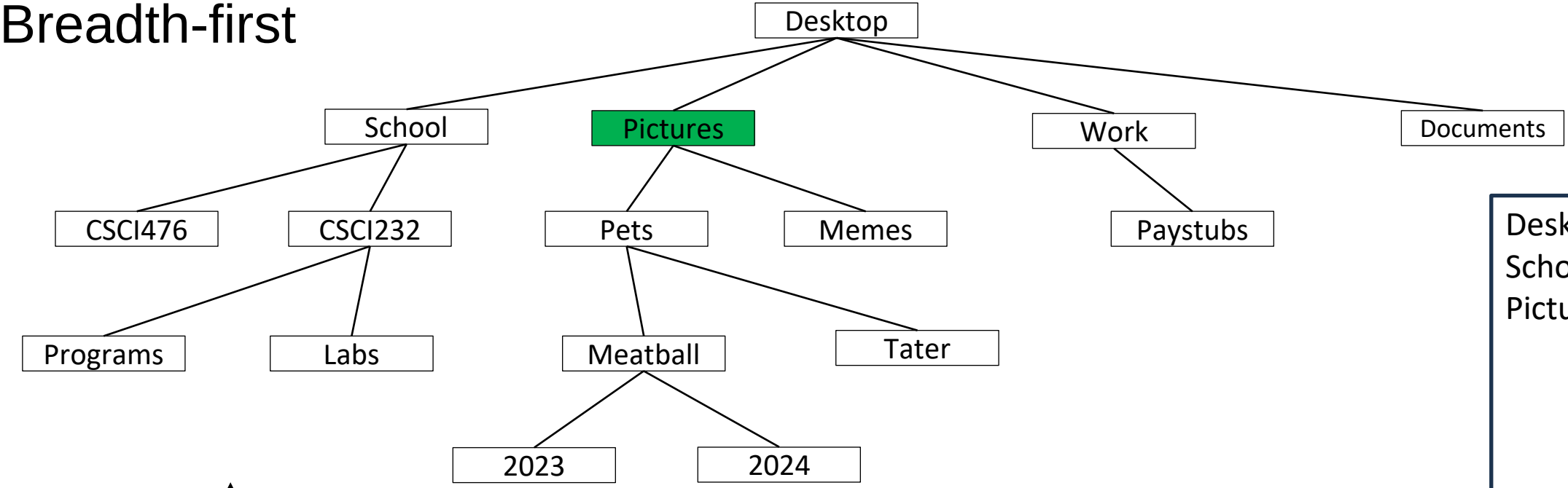
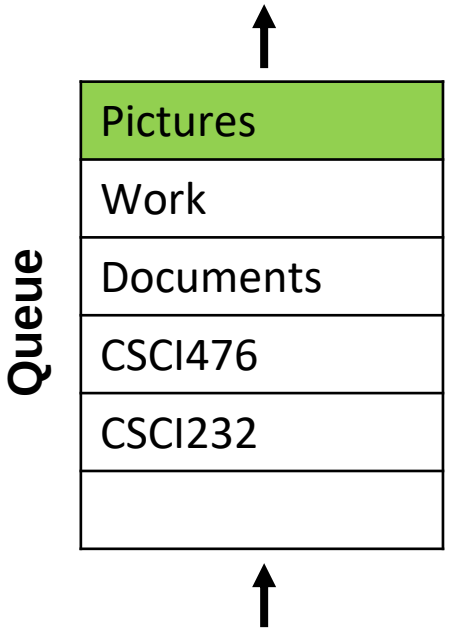


Output

Desktop
School
Pictures



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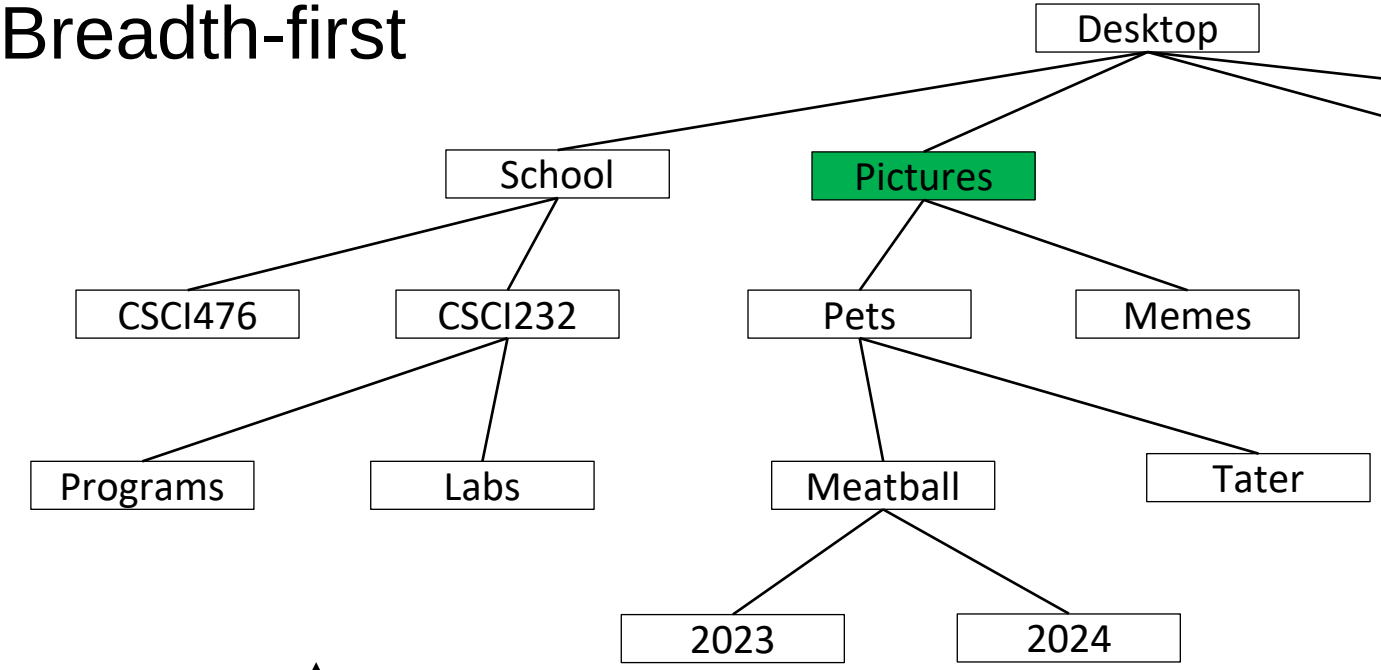

Output

Desktop
School
Pictures

Queue

Pictures
Work
Documents
CSCI476
CSCI232
Pets
Memes

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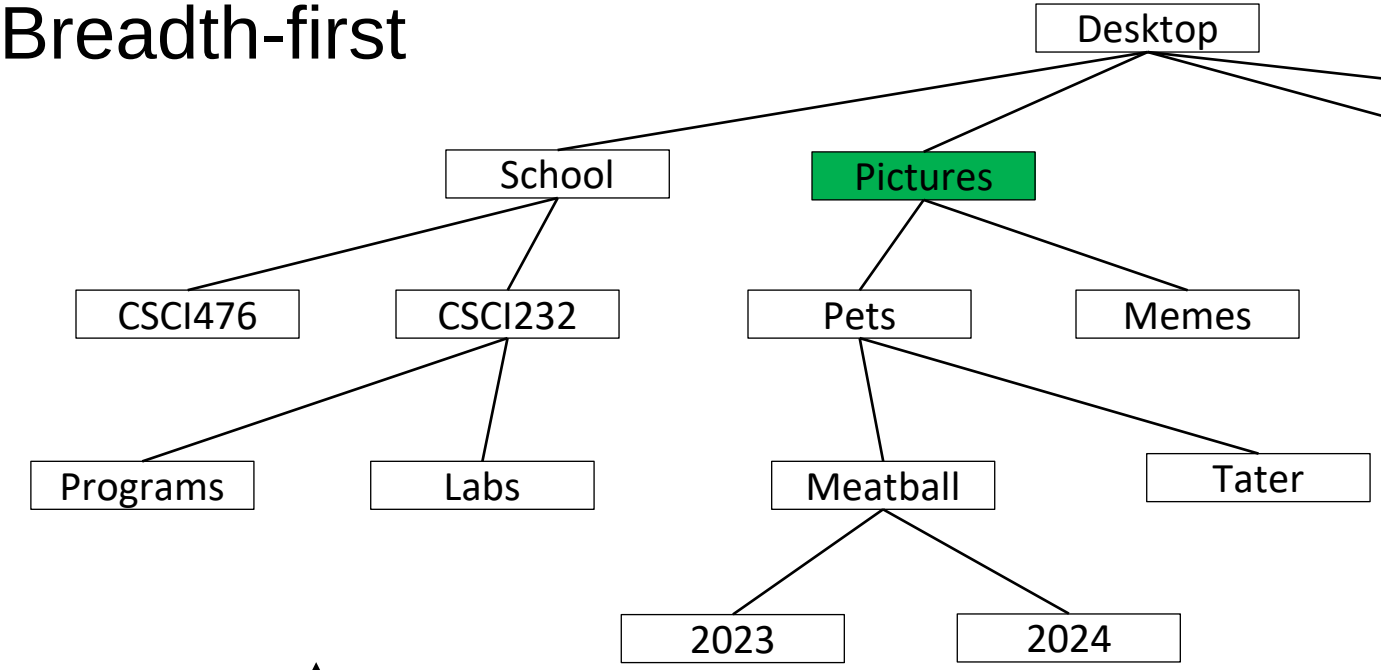

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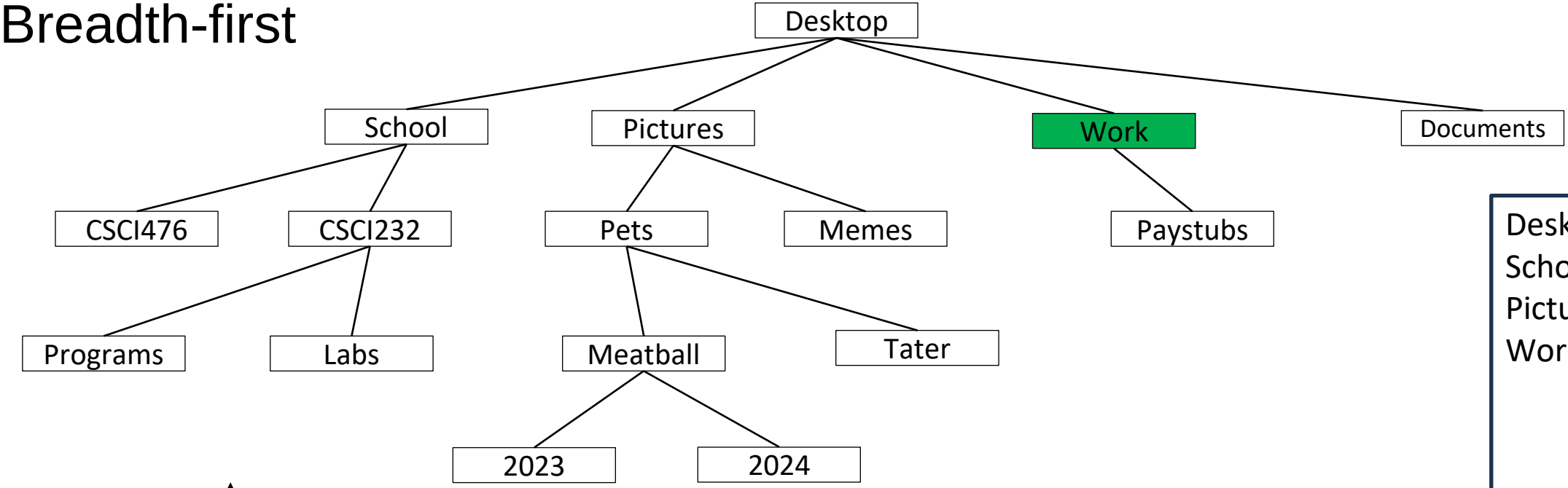
3. Remove visited node from the queue

Breadth-first



Output

Desktop
School
Pictures
Work

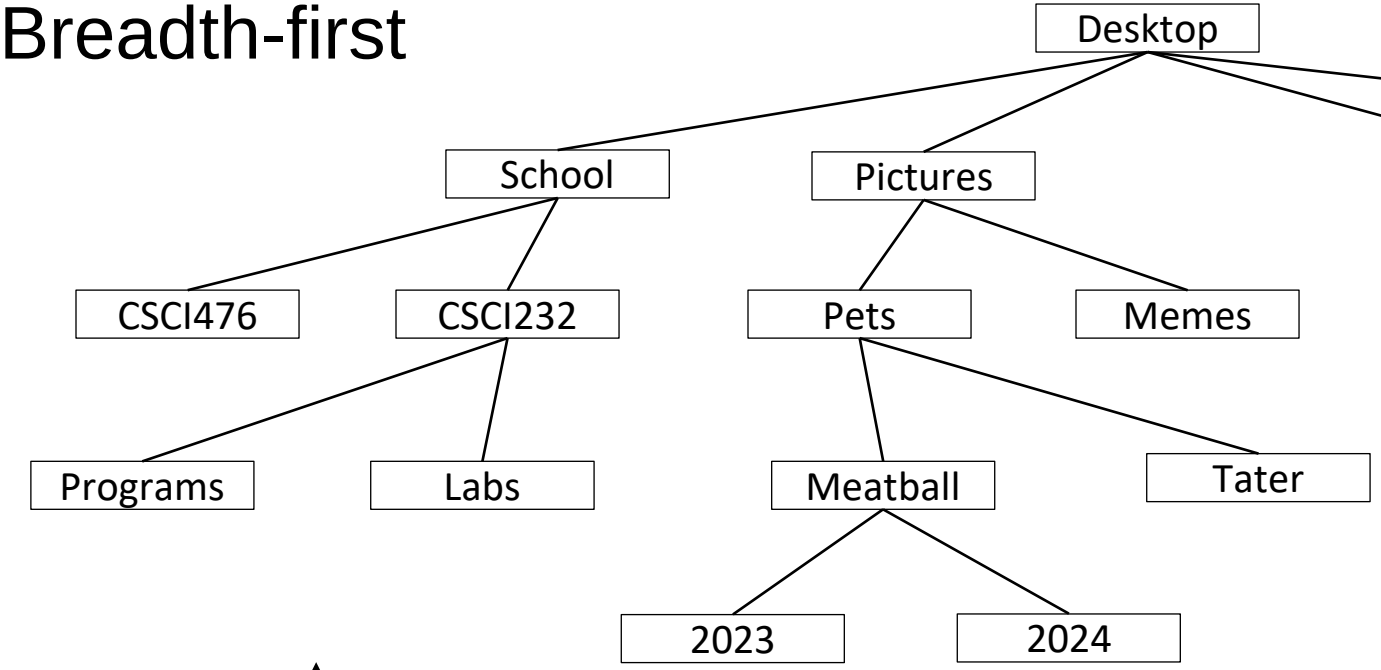
Queue

Work
Documents
CSCI476
CSCI232
Pets
Memes

Every time we "visit" a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

Breadth-first



Output

Desktop
School
Pictures
Work

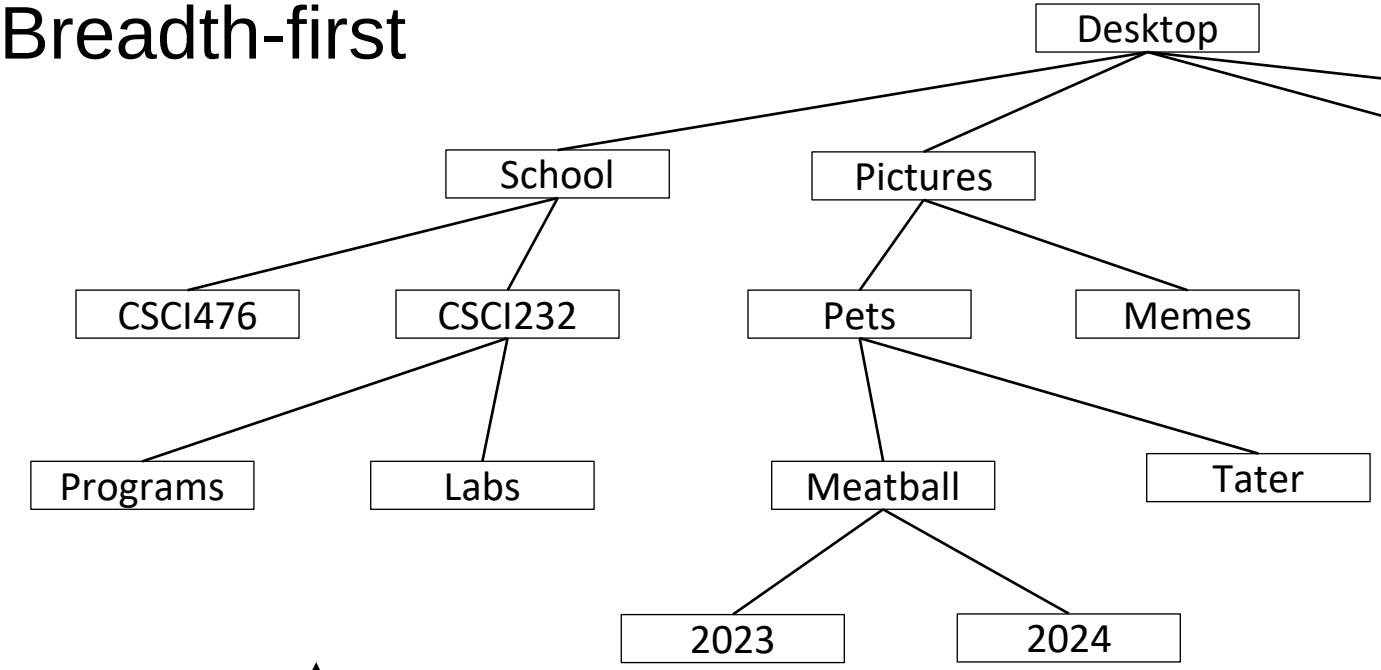
Queue

Work
Documents
CSCI476
CSCI232
Pets
Memes
Paystubs

Every time we "visit" a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

Breadth-first



Output

Desktop
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Work

Queue

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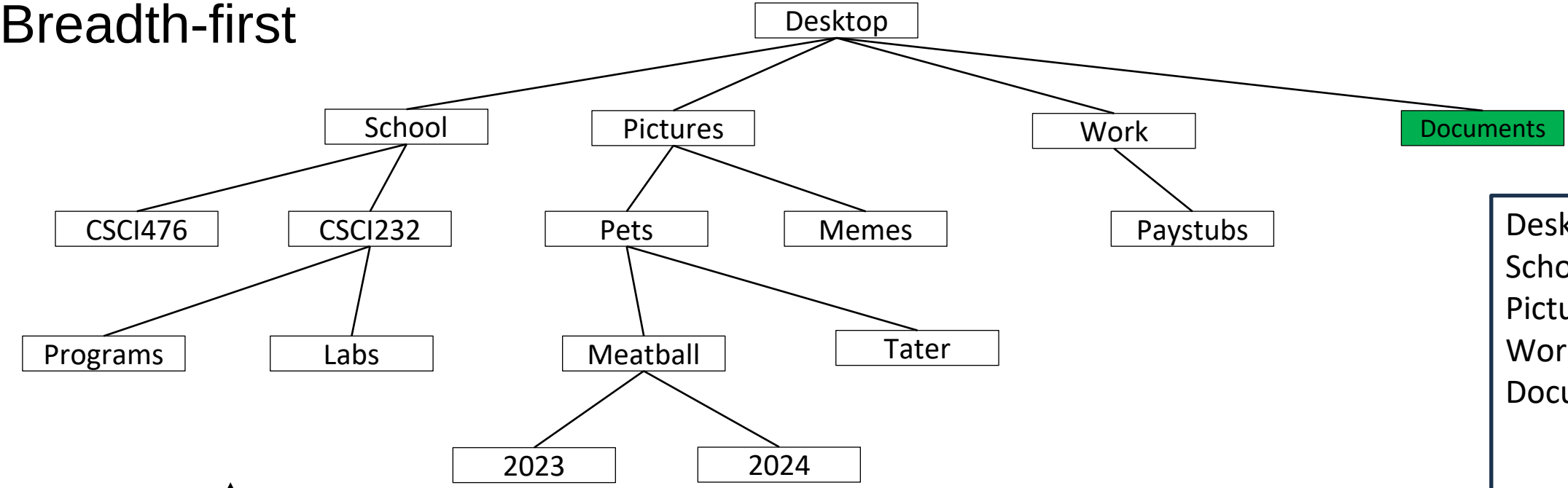
Pets
Memes
Paystubs

Every time we "visit" a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

Breadth-first



Output

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Work
Documents

Queue

Documents
CSCI476
CSCI232
Pets
Memes
Paystubs

Every time we "visit" a node we:

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2. Add all of its children to the queue
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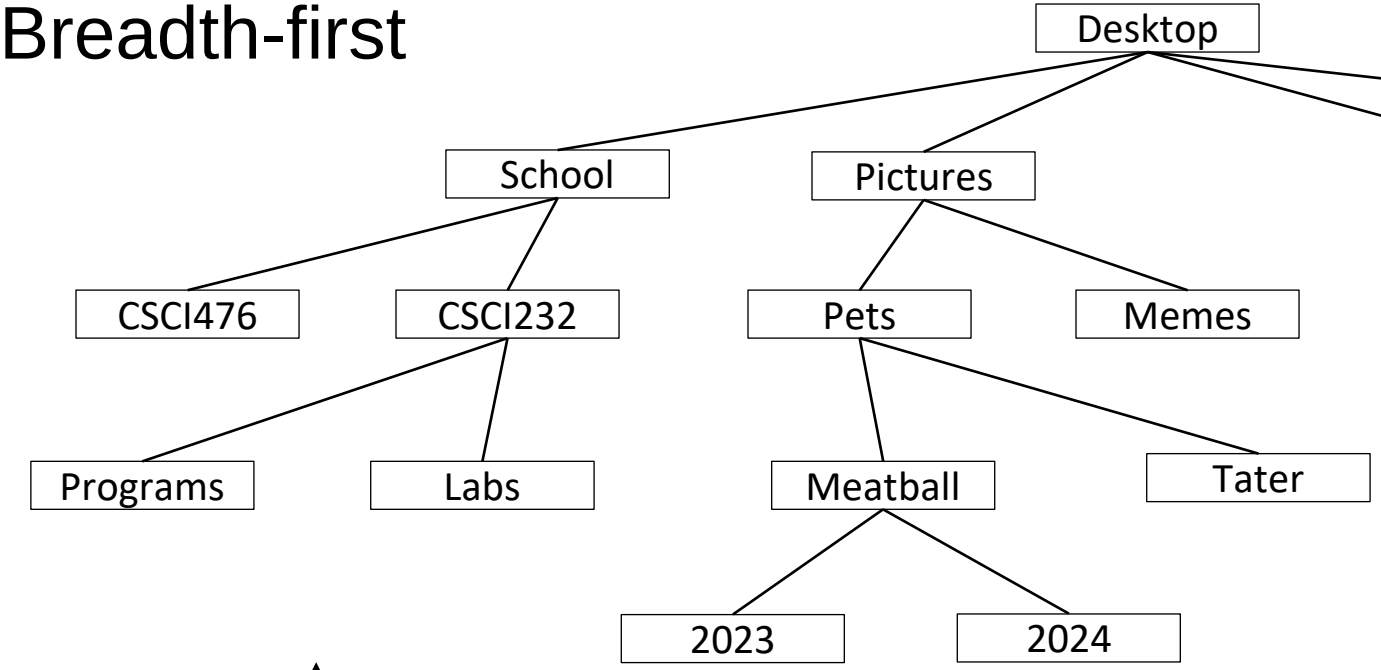
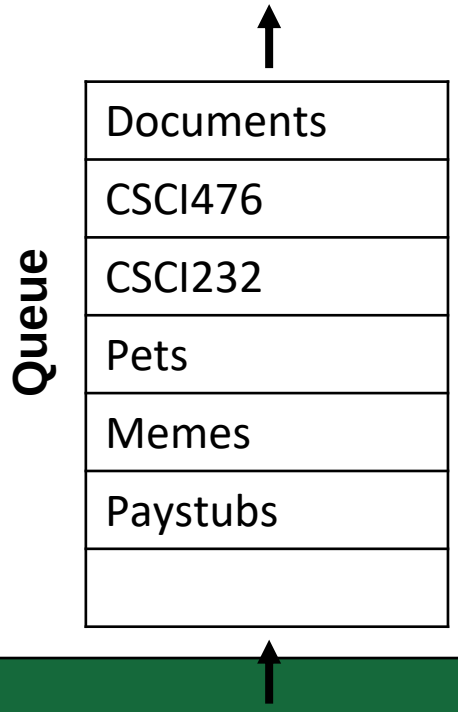
Breadth-first



Output

Desktop
School
Pictures
Work
Documents

Queue



Every time we "visit" a node we:

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2. Add all of its children to the queue
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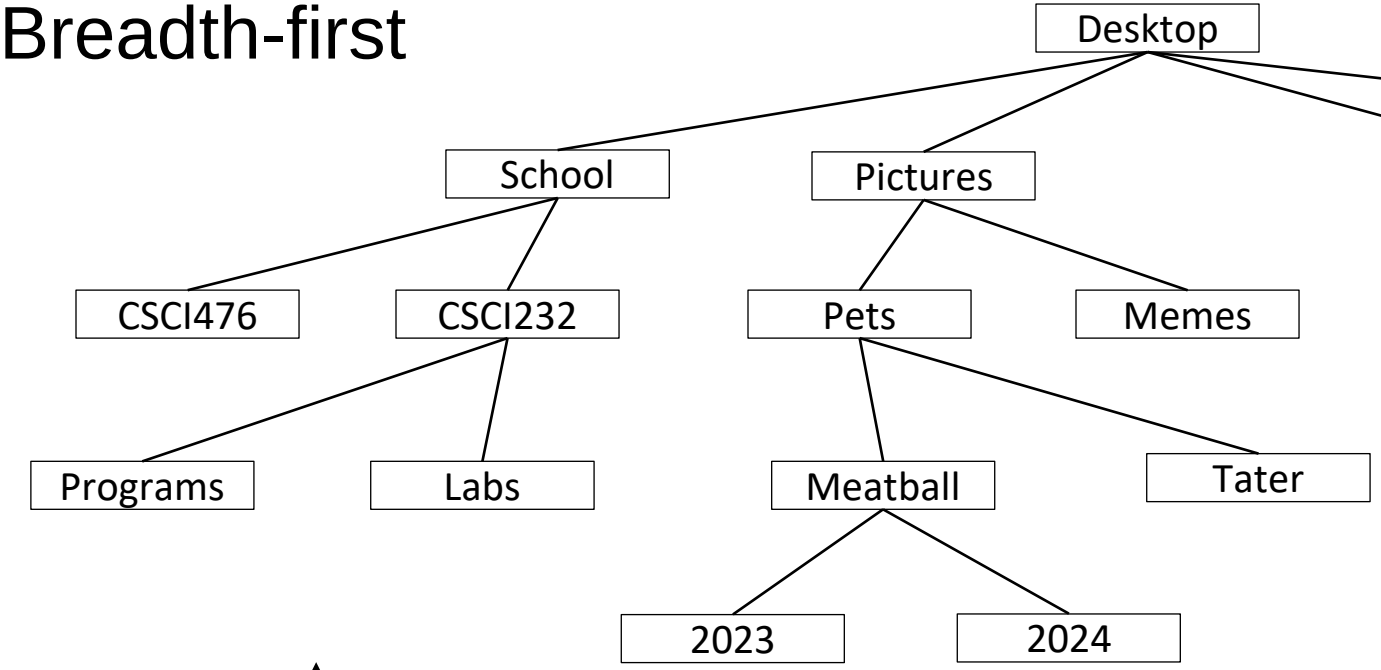
Breadth-first



Output

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Every time we "visit" a node we:

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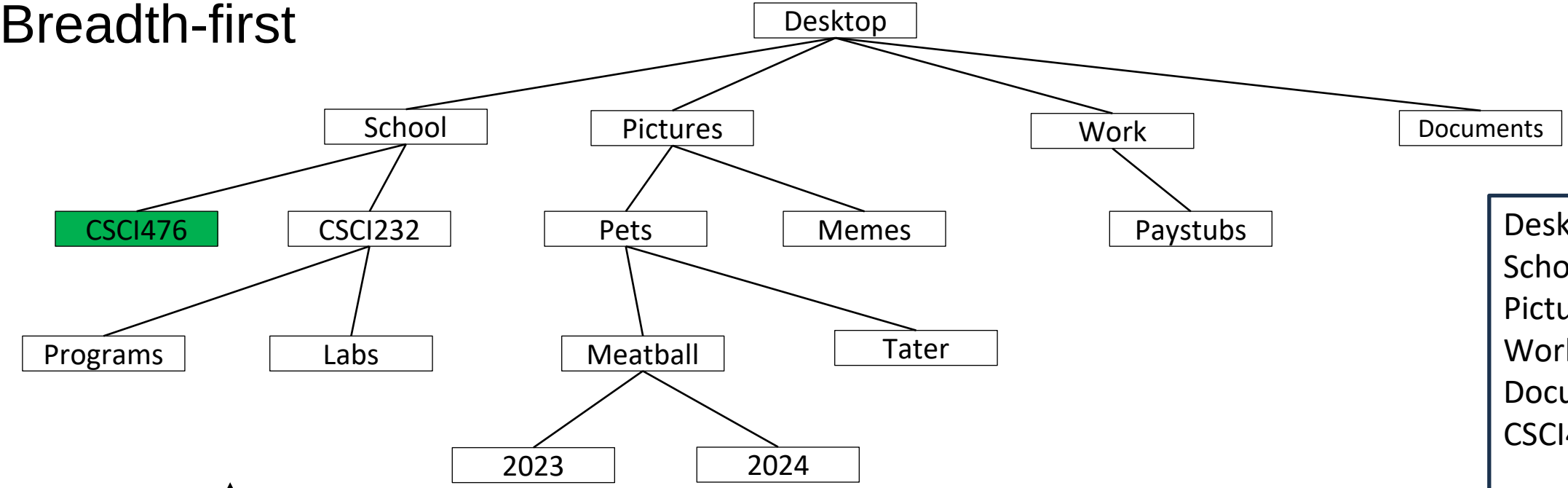
2. Add all of its children to the queue
3. Remove visited node from the queue

Breadth-first



Output

Desktop
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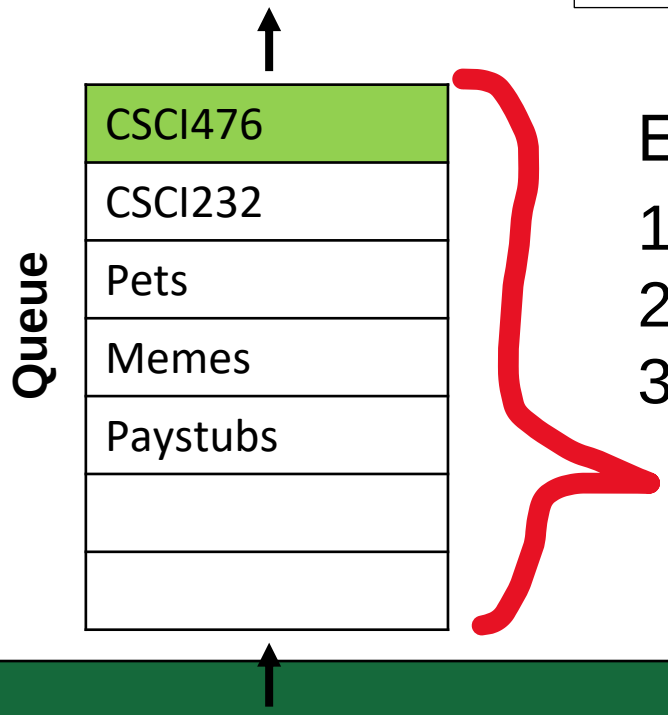
CSCI476



Every time we "visit" a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

Because of step 2, we can visit nodes in the proper order in layer two !

Breadth-first

```
public void breadthFirst(){




}
```

Every time we “visit” a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

Breadth-first

```
public void breadthFirst(){
        Queue<???> = new ???<???>();









}
```

Every time we “visit” a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

Breadth-first

```
public void breadthFirst(){
        Queue<Node> = new LinkedList<Node>();









}
```

Every time we “visit” a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

Breadth-first

```
public void breadthFirst(){
        Queue<Node> = new LinkedList<Node>();









}
```

Every time we “visit” a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

Where do we start at ?

Breadth-first

```
public void breadthFirst(){
        Queue<Node> = new LinkedList<Node>();
        if( root != null){
                queue.add(root)









        }
}
```

Every time we “visit” a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

Where do we start at ? **THE ROOT**

Breadth-first

```
public void breadthFirst(){
        Queue<Node> = new LinkedList<Node>();
        if( root != null){
                queue.add(root)









        }
}
```

Every time we “visit” a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

How long to loop for?

Breadth-first

```
public void breadthFirst(){
        Queue<Node> = new LinkedList<Node>();
        if( root != null){
                queue.add(root)
                while( !queue.isEmpty() ){









                }

        }
}
```

Every time we “visit” a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

How long to loop for? As long as our queue as unvisited nodes inside of it

Breadth-first

```
public void breadthFirst(){
        Queue<Node> = new LinkedList<Node>();
        if( root != null){
                queue.add(root)
                while( !queue.isEmpty() ){


                        Node node = queue.remove()









                }

        }
}
```

Every time we “visit” a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

In order to execute the Node action, I need to retrieve the next node. However, I am going to retrieve and remove it in the same step

Breadth-first

```
public void breadthFirst(){
        Queue<Node> = new LinkedList<Node>();
        if( root != null){
                queue.add(root)
                while( !queue.isEmpty() ){


                        Node node = queue.remove()

                        System.out.println(node.get???)









                }

        }
}
```

Every time we “visit” a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
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In order to execute the Node action, I need to retrieve the next node. However, I am going to retrieve and remove it in the same step

Breadth-first

```
public void breadthFirst(){
        Queue<Node> = new LinkedList<Node>();
        if( root != null){
                queue.add(root)
                while( !queue.isEmpty() ){


                        Node node = queue.remove()

                        System.out.println(node.get???)

                        for(Node n: node.getChildren()){


                        }

                }

        }
}
```

Every time we “visit” a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
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public void breadthFirst(){
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                        System.out.println(node.get???)

                        for(Node n: node.getChildren()){
                                queue.add(n);
                        }

                }

        }
}
```

Every time we “visit” a node we:

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Breadth-first

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public void breadthFirst(){
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                queue.add(root)
                while( !queue.isEmpty() ){


                        Node node = queue.remove()

                        System.out.println(node.get???)

                        for(Node n: node.getChildren()){
                                queue.add(n);
                        }

                }

        }
}
```
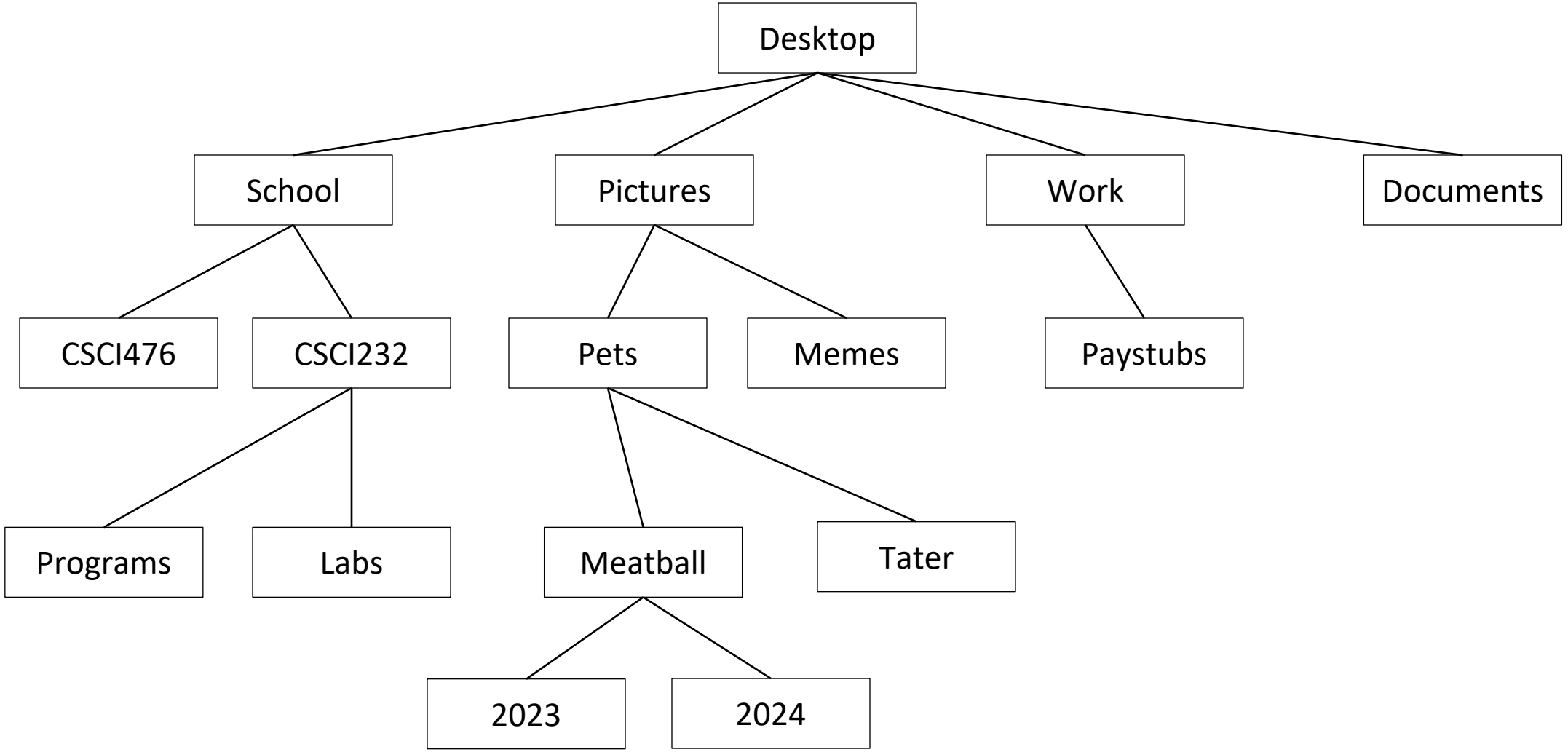

Every time we "visit" a node we:

1. Execute the action (e.g., print, compare, …)
2. Add all of its children to the queue
3. Remove visited node from the queue

Let's code this!


Desktop
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Paystubs
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Meatball
Tater
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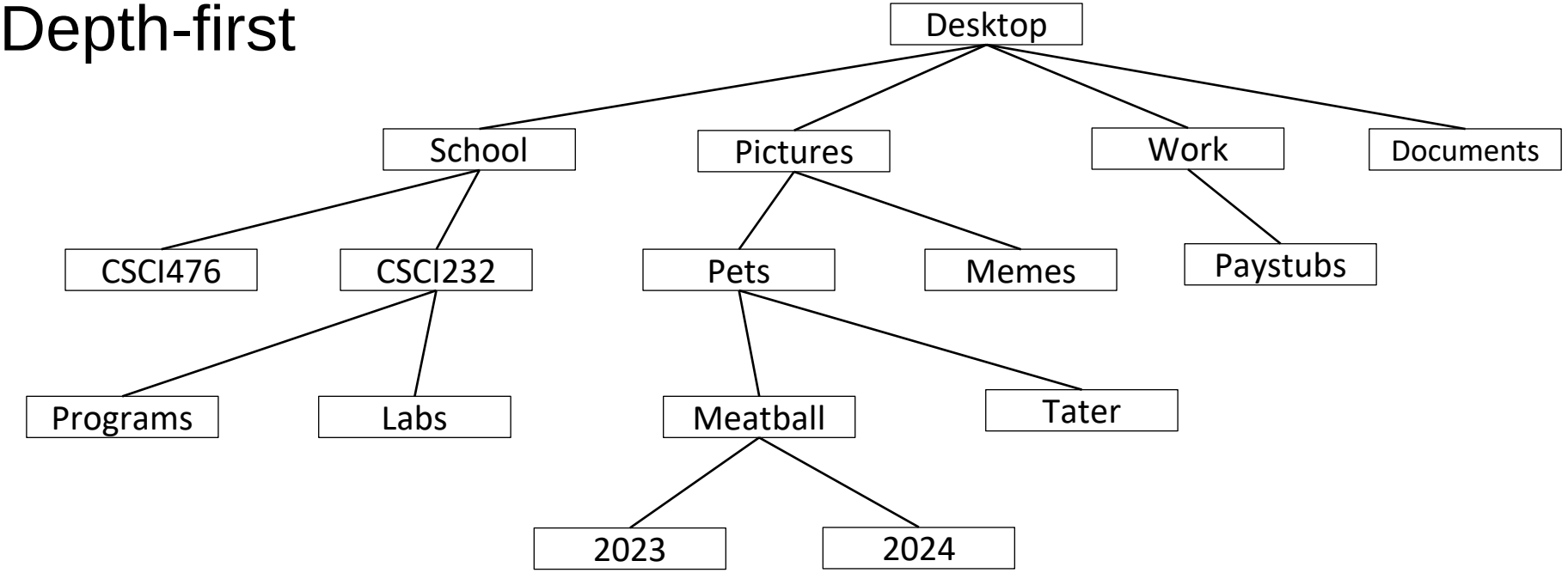
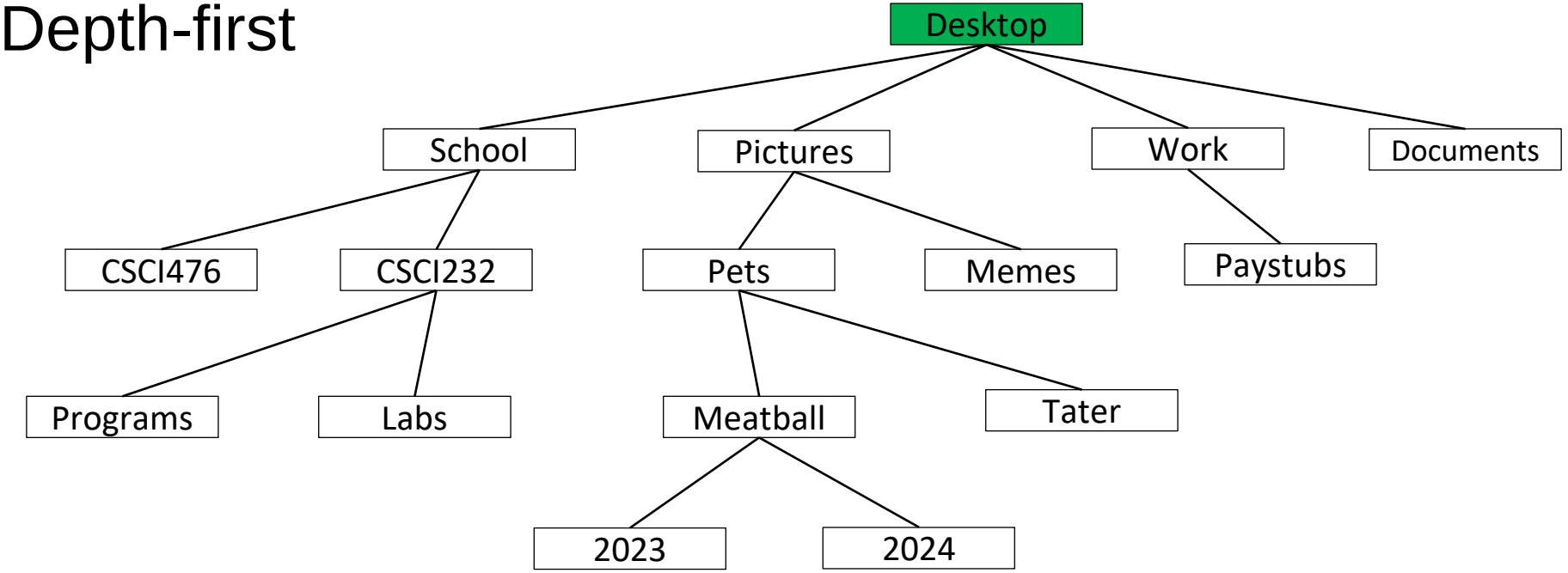
2024

Depth-first



Output

Depth-first

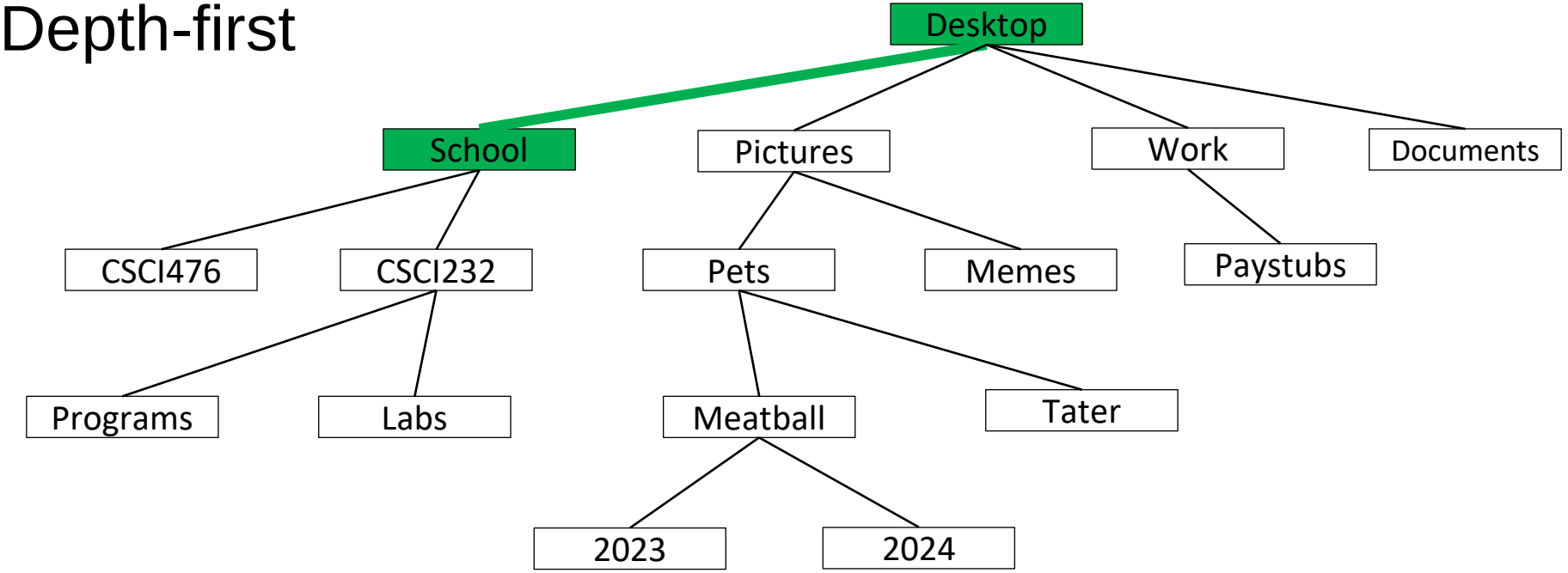


Output

Desktop

1. Go all the way down the “first” leaf

Depth-first

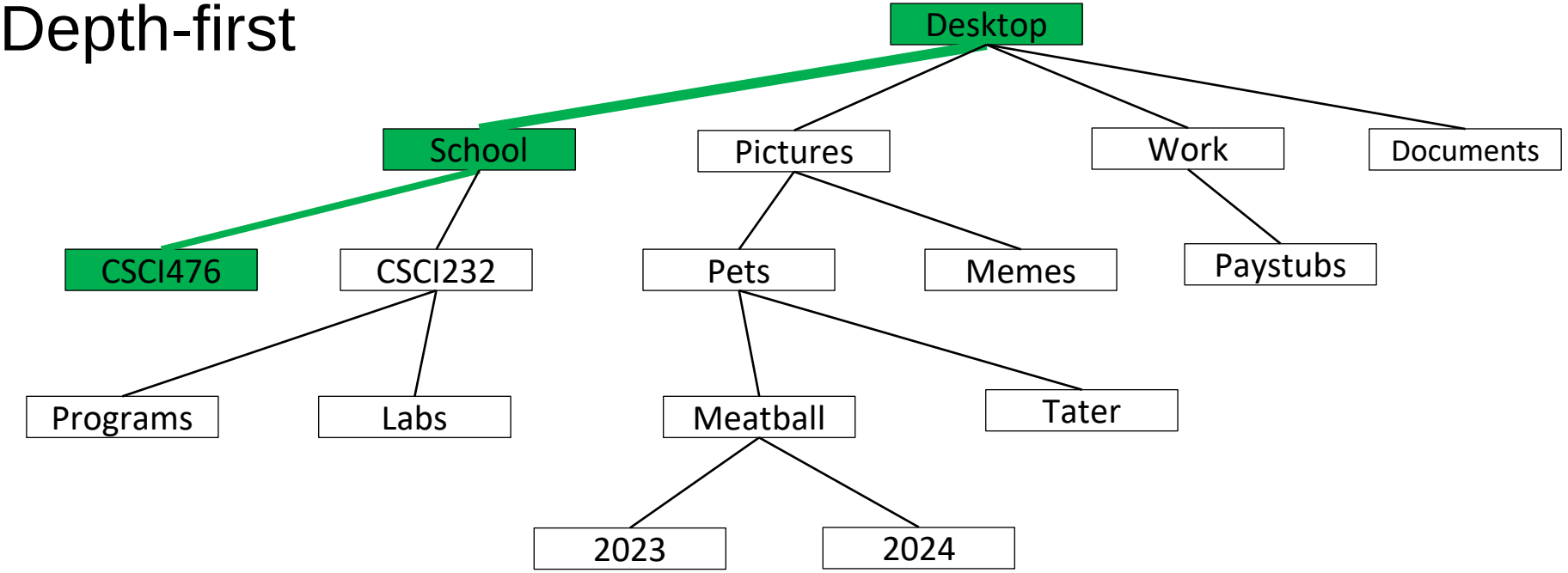


Output

Desktop
School

1. Go all the way down the “first” leaf

Depth-first



Output

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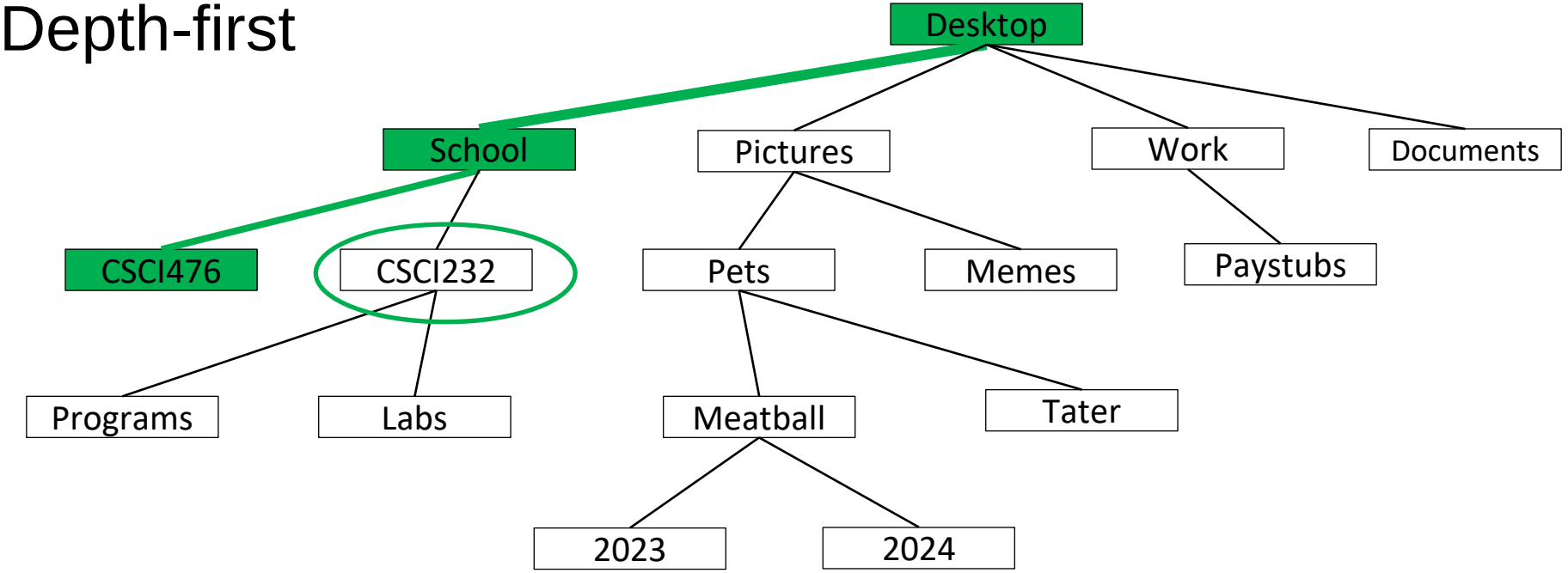
School
CSCI476

1. Go all the way down the “first” leaf

Depth-first

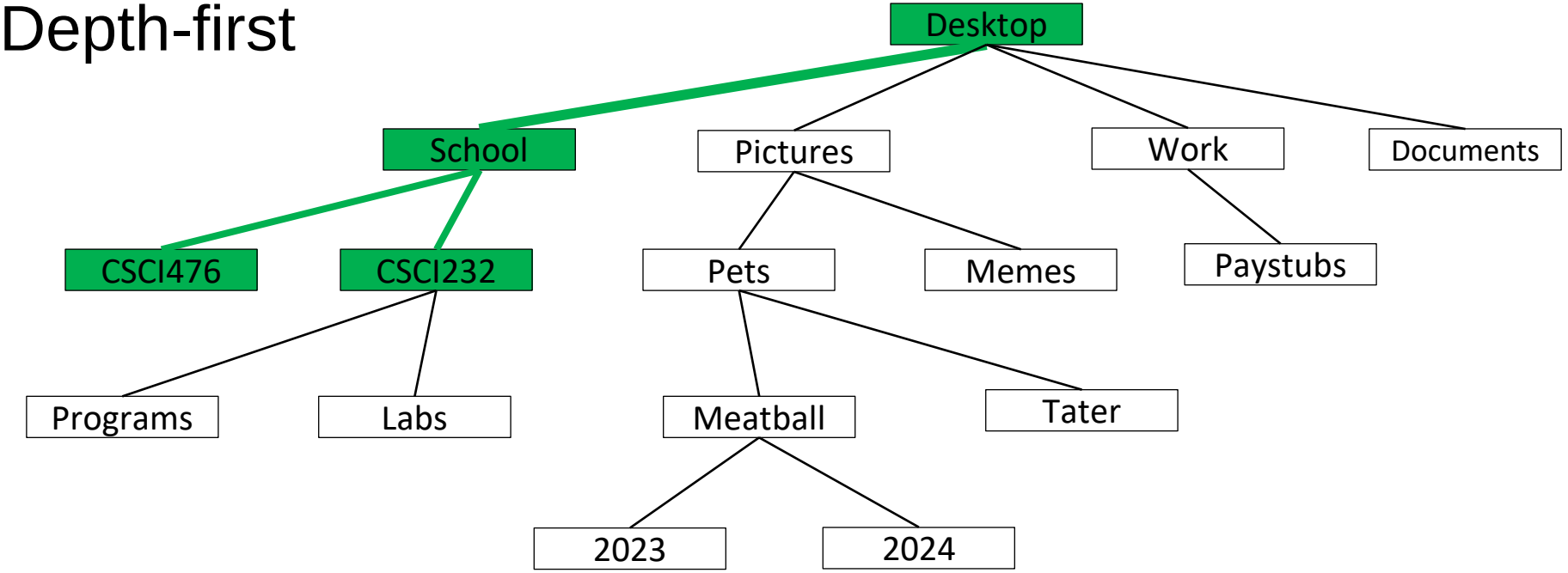


Output

Desktop
School
CSCI476

1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered

Depth-first

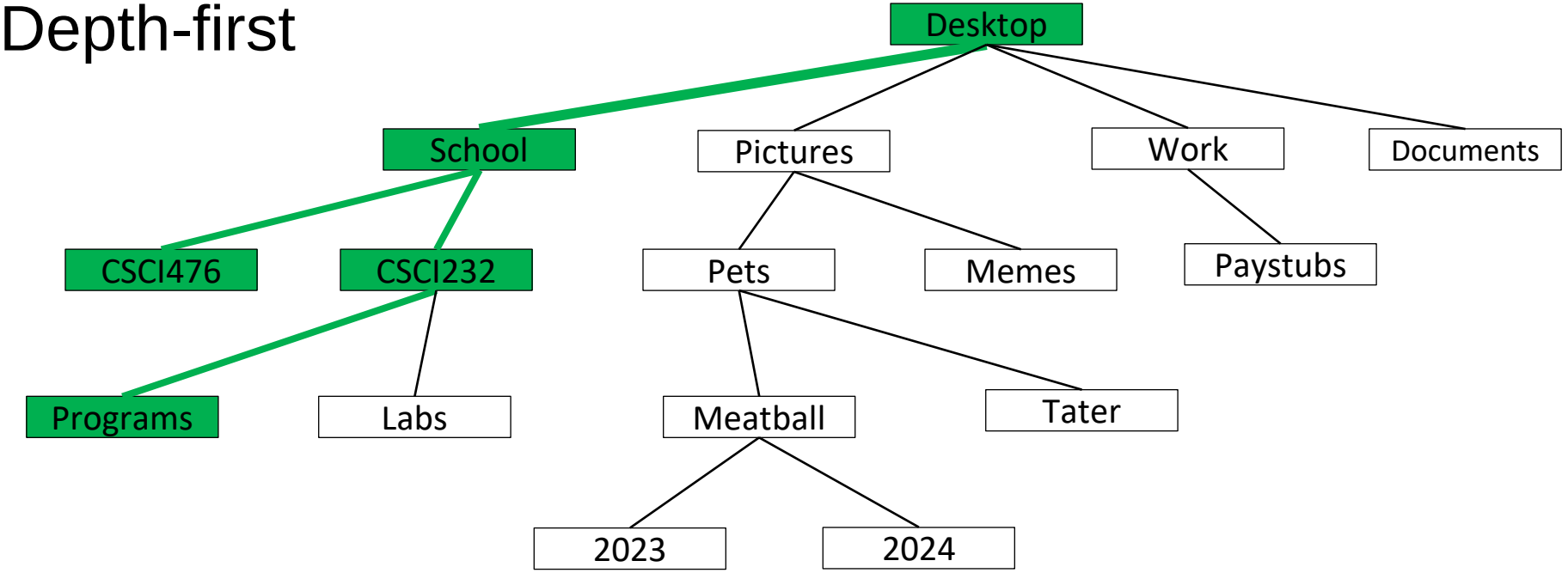


Output

Desktop
School
CSCI476
CSCI 232

1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered

Depth-first

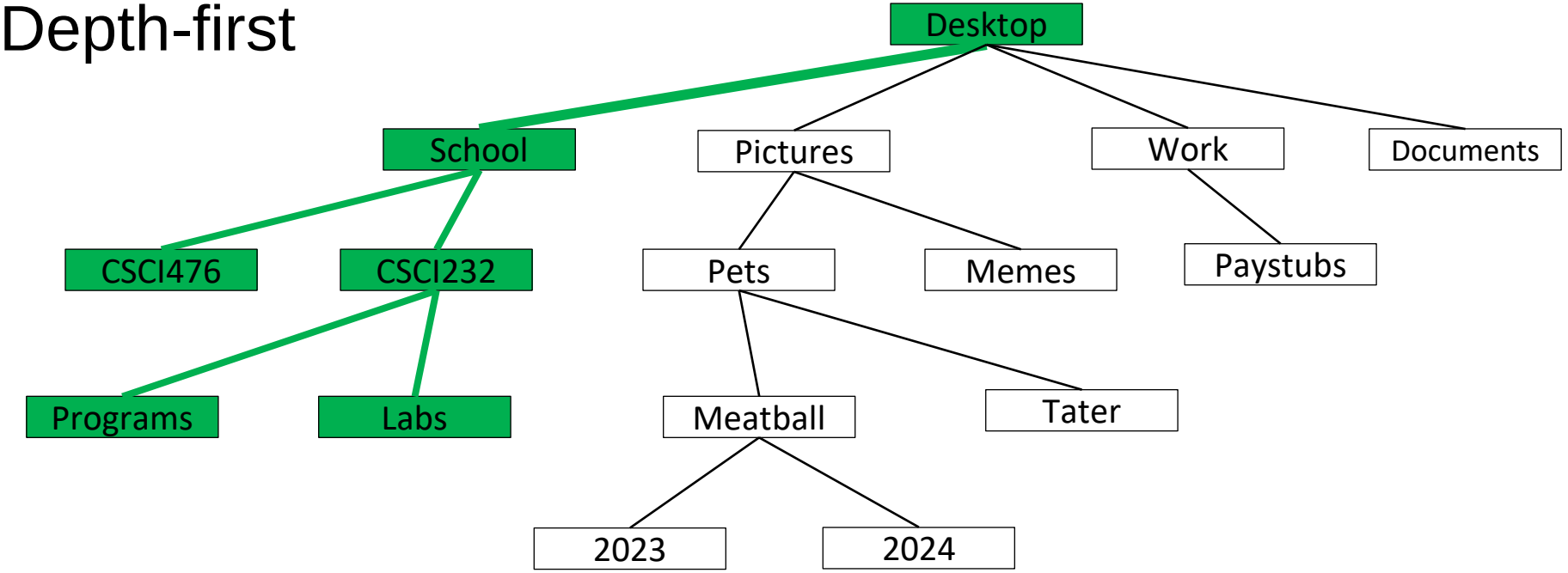


Output

Desktop
School
CSCI476
CSCI 232
Programs

1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered

Depth-first



Output

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CSCI 232
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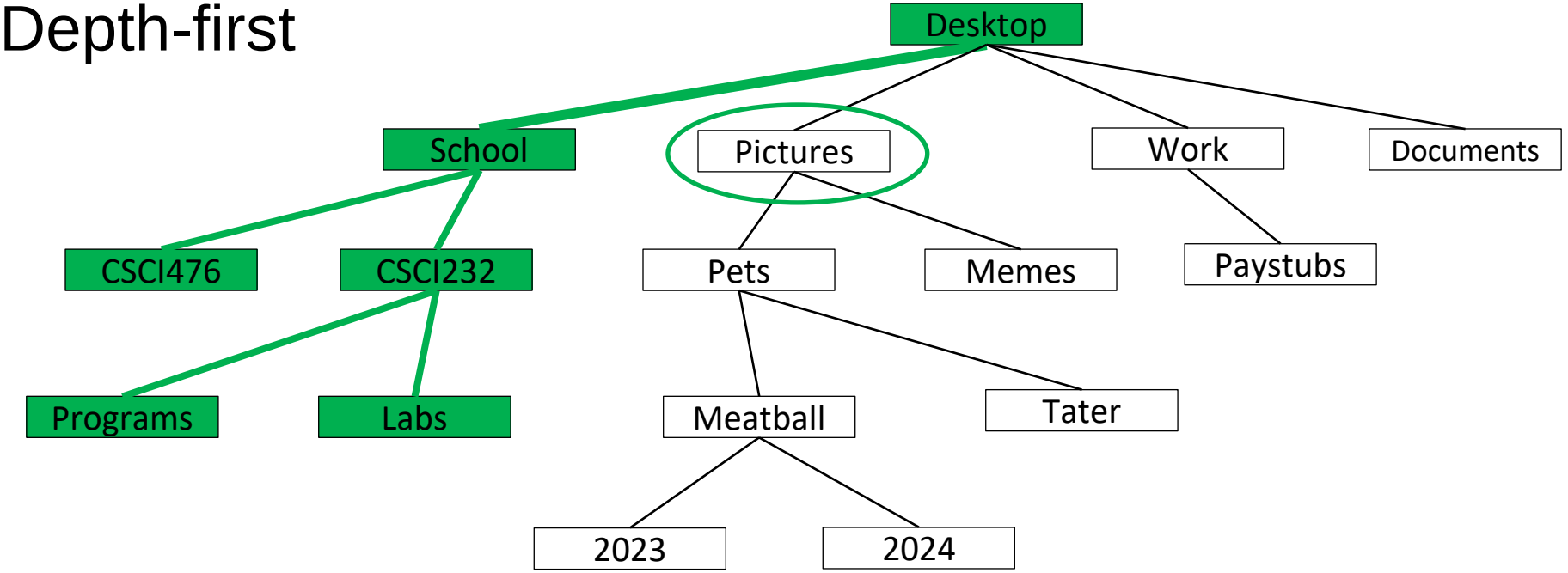
Labs

1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered

Depth-first

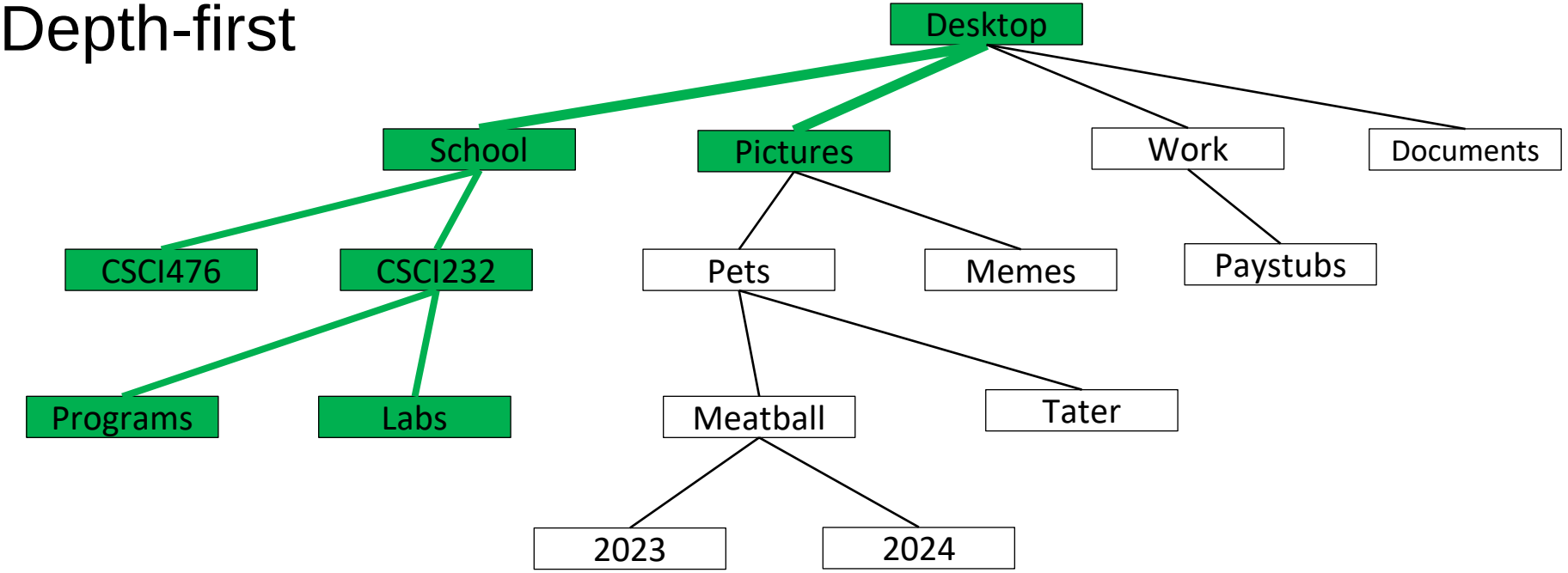


Output

Desktop
School
CSCI476
CSCI 232
Programs
Labs

1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered

Depth-first



Output

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Programs
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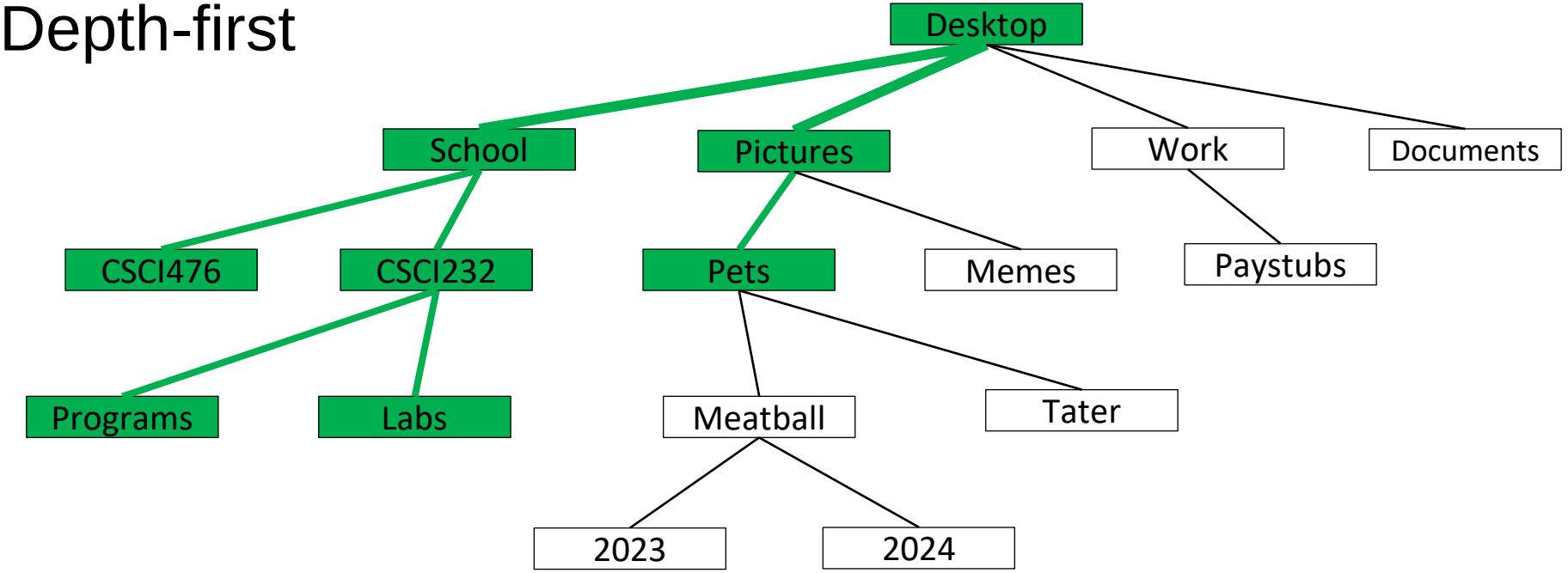
1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
3. Repeat

Depth-first



Output

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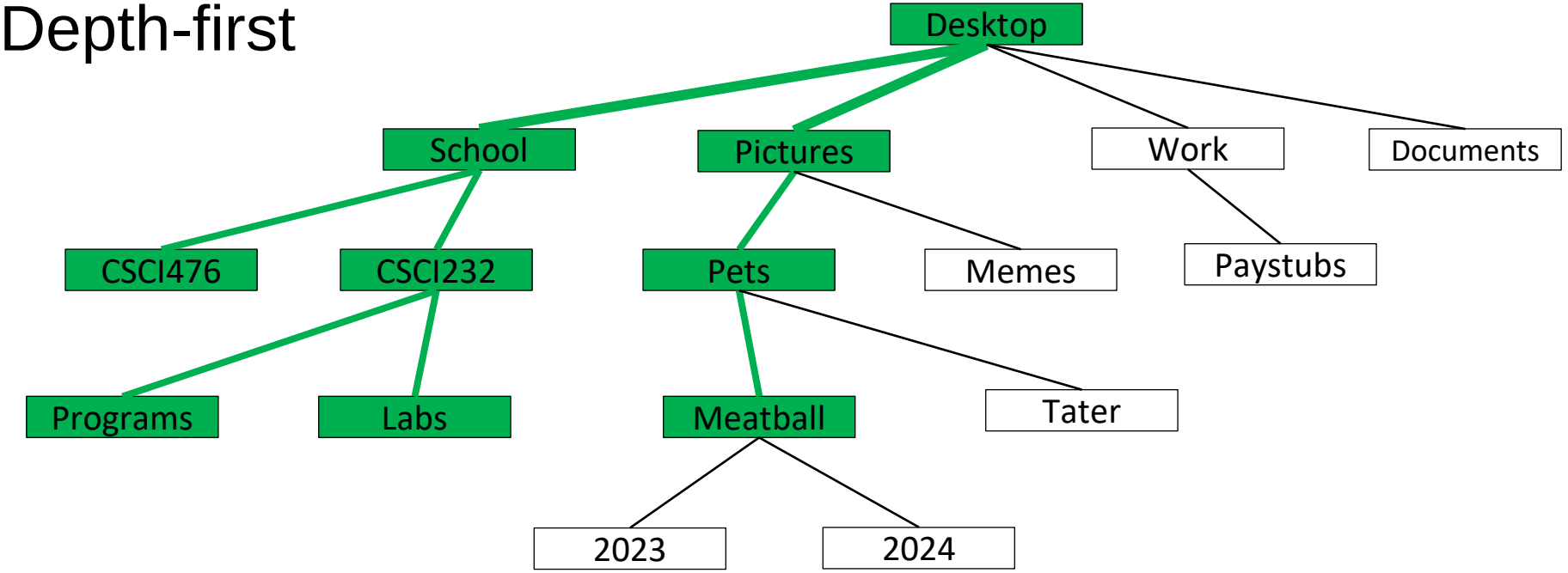
Pets

1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
3. Repeat

Depth-first



Output

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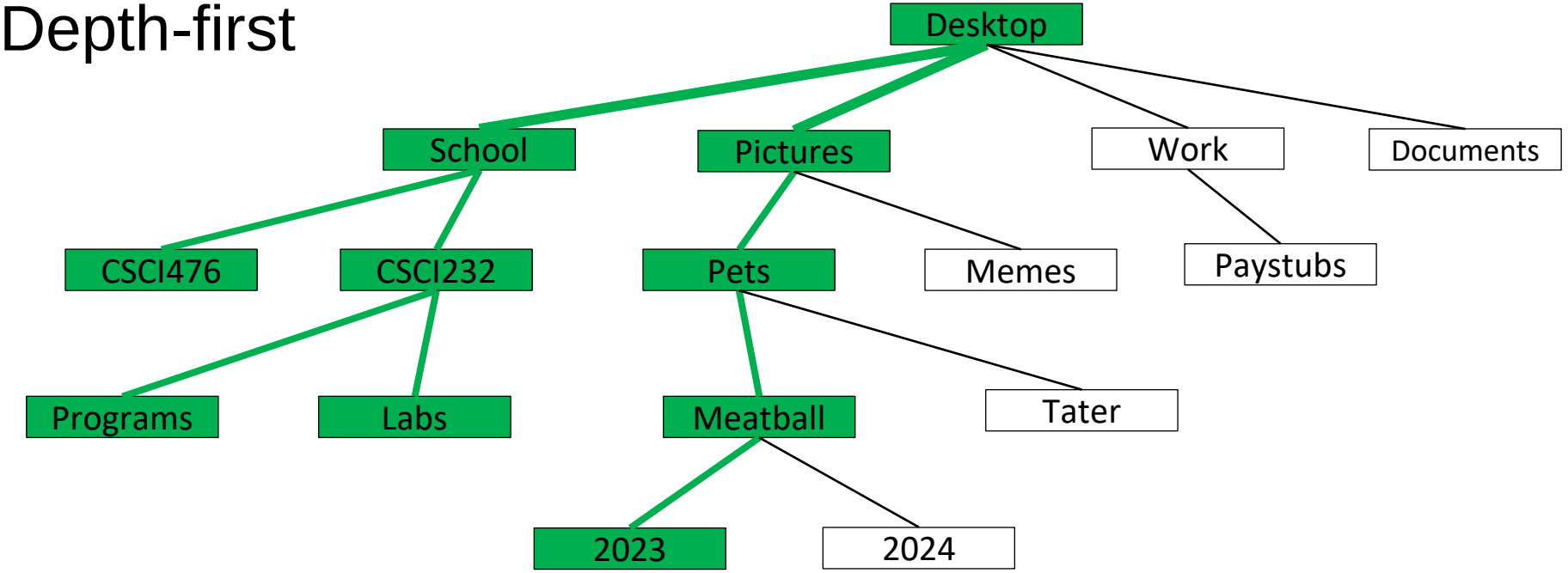
Pets
Meatball

1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
3. Repeat

Depth-first



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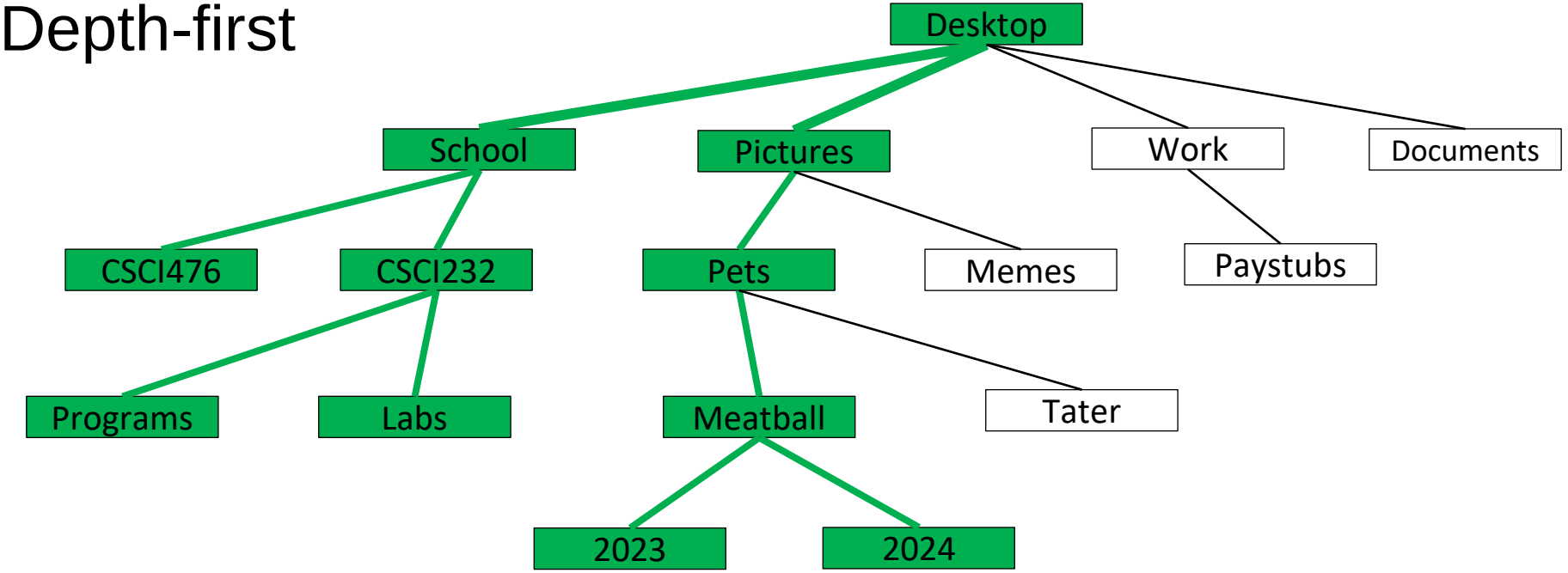
1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
3. Repeat

Depth-first



Output

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1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
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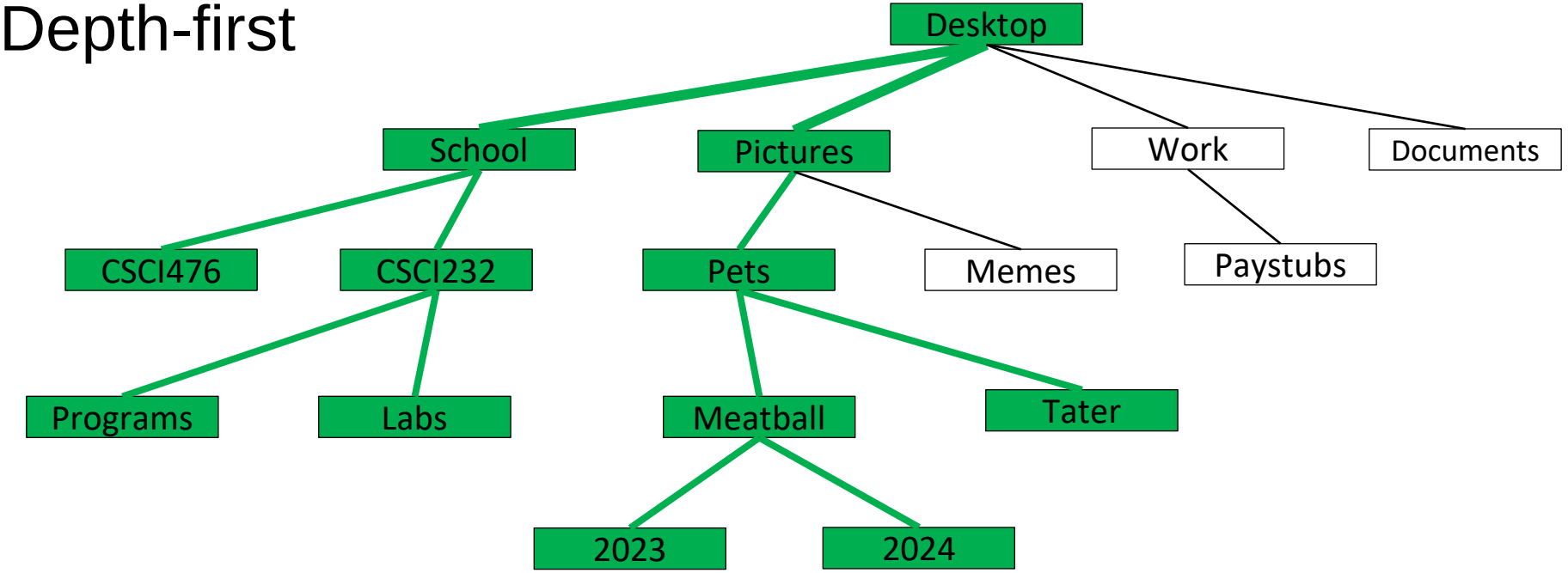
Depth-first



Output

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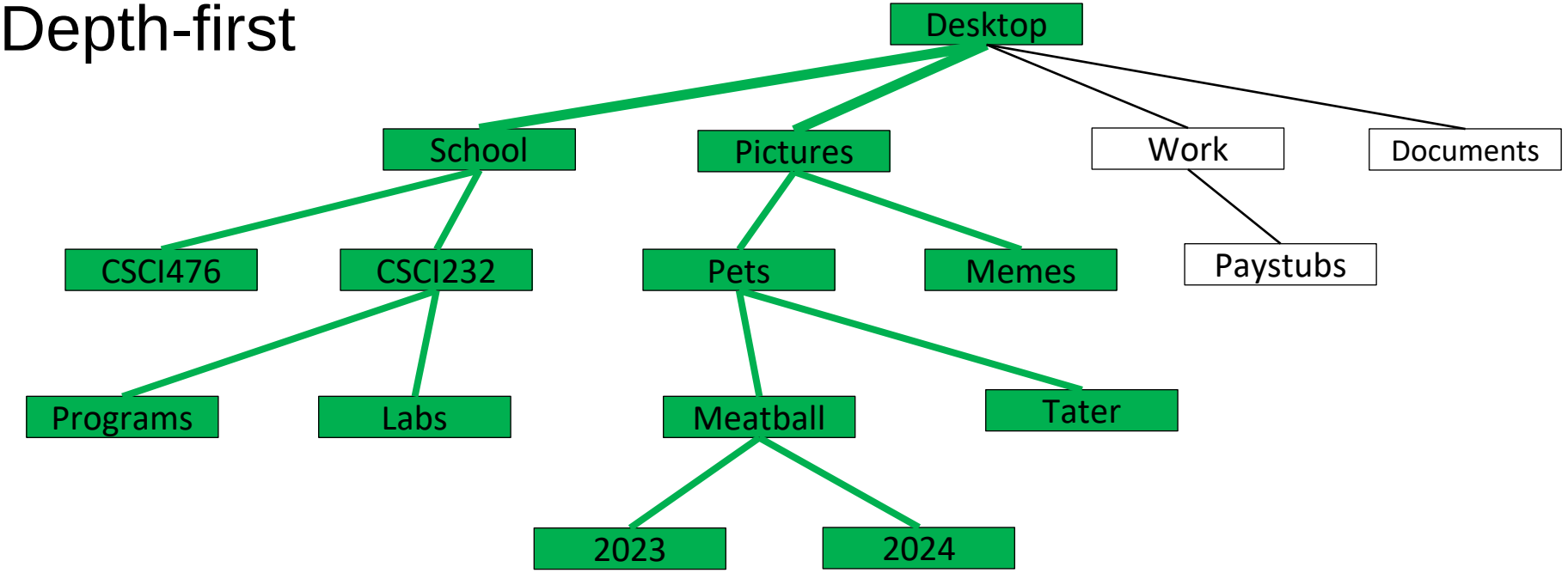
1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
3. Repeat

Depth-first



Output

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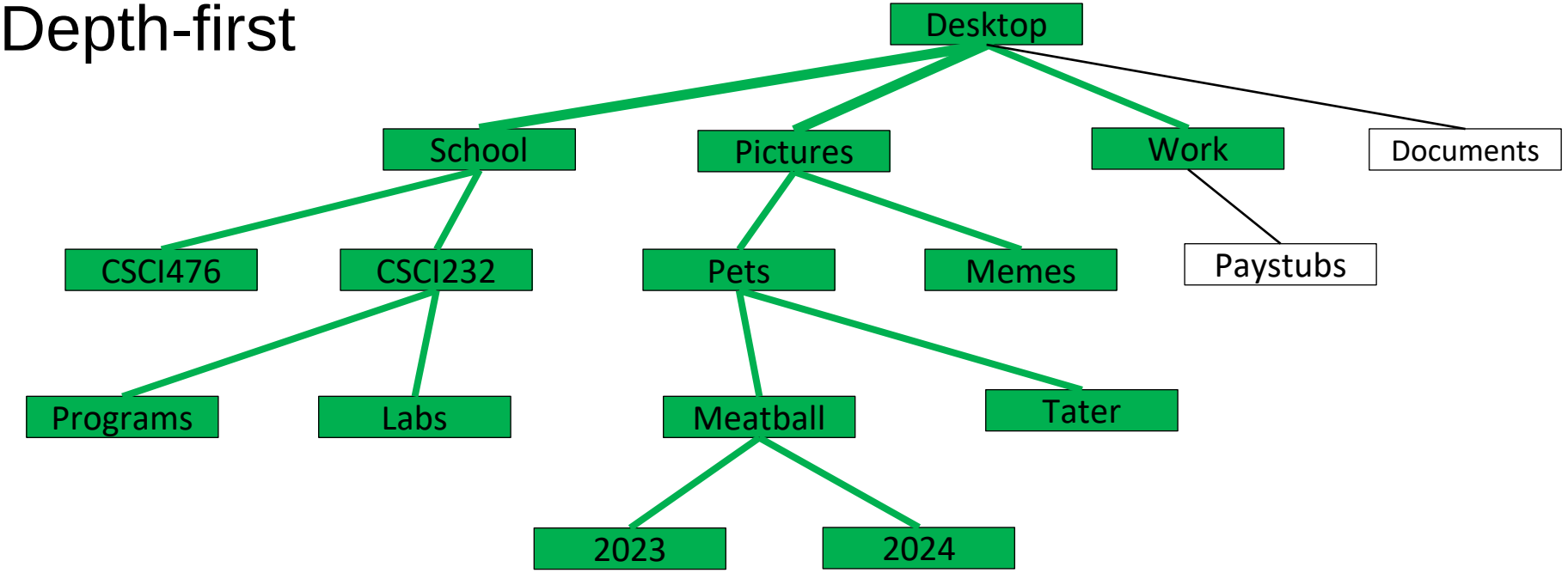
Memes

1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
3. Repeat

Depth-first



Output

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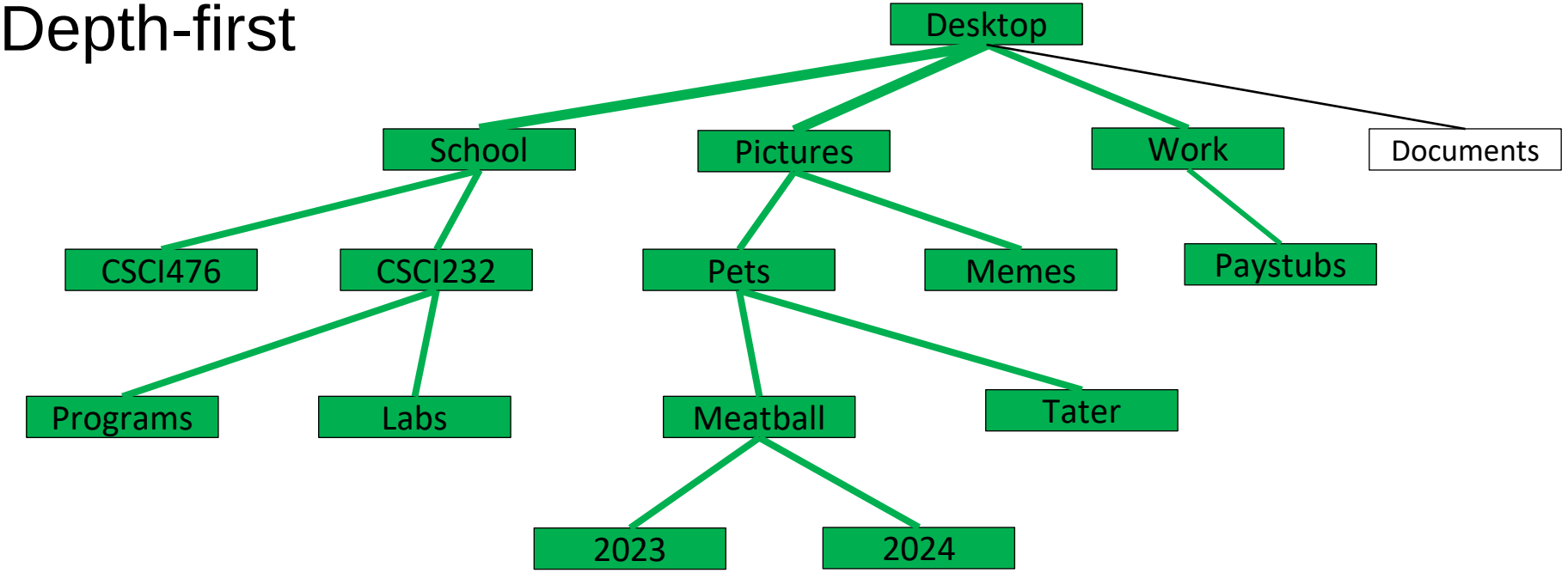
1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
3. Repeat

Depth-first



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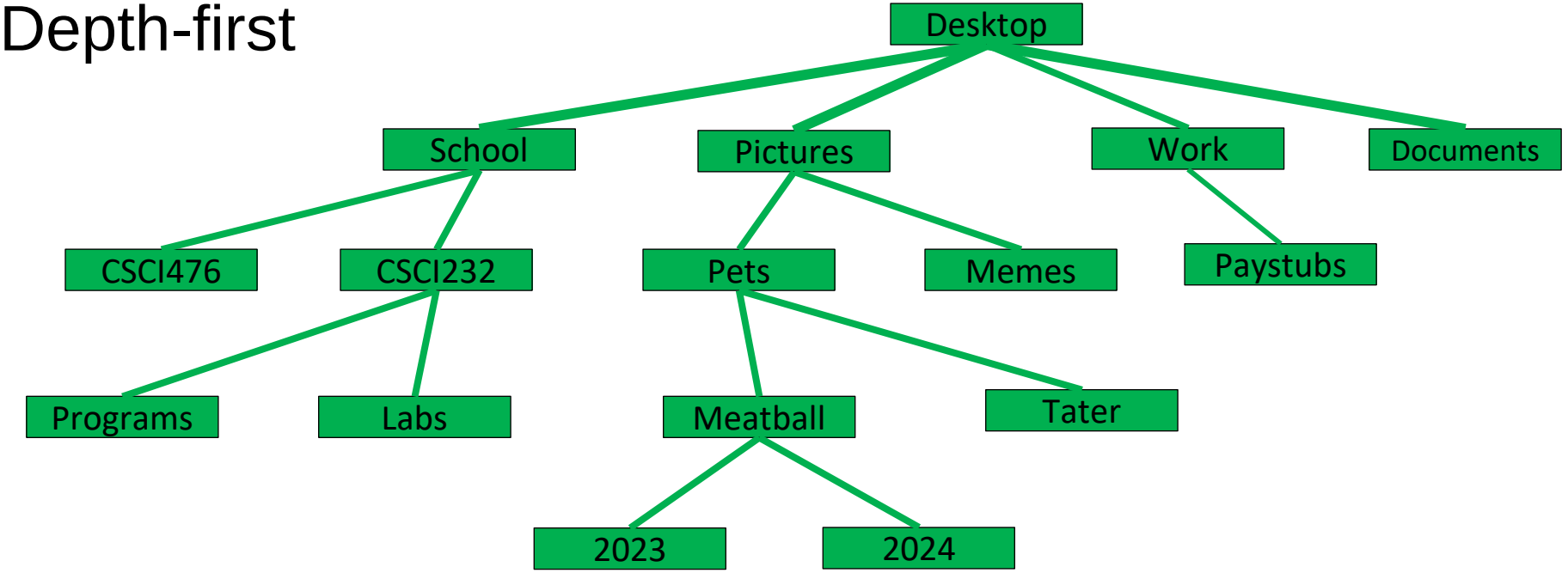
1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
3. Repeat

Depth-first



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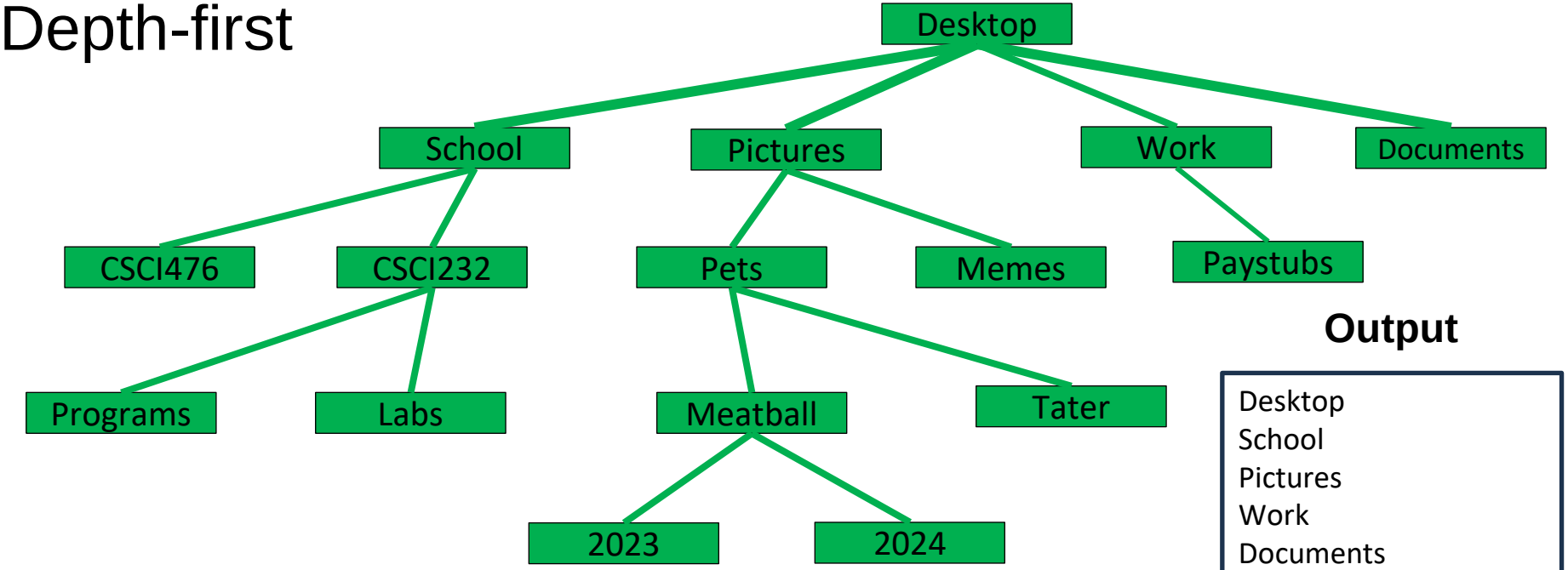
1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
3. Repeat

Depth-first



Output

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Breadth First

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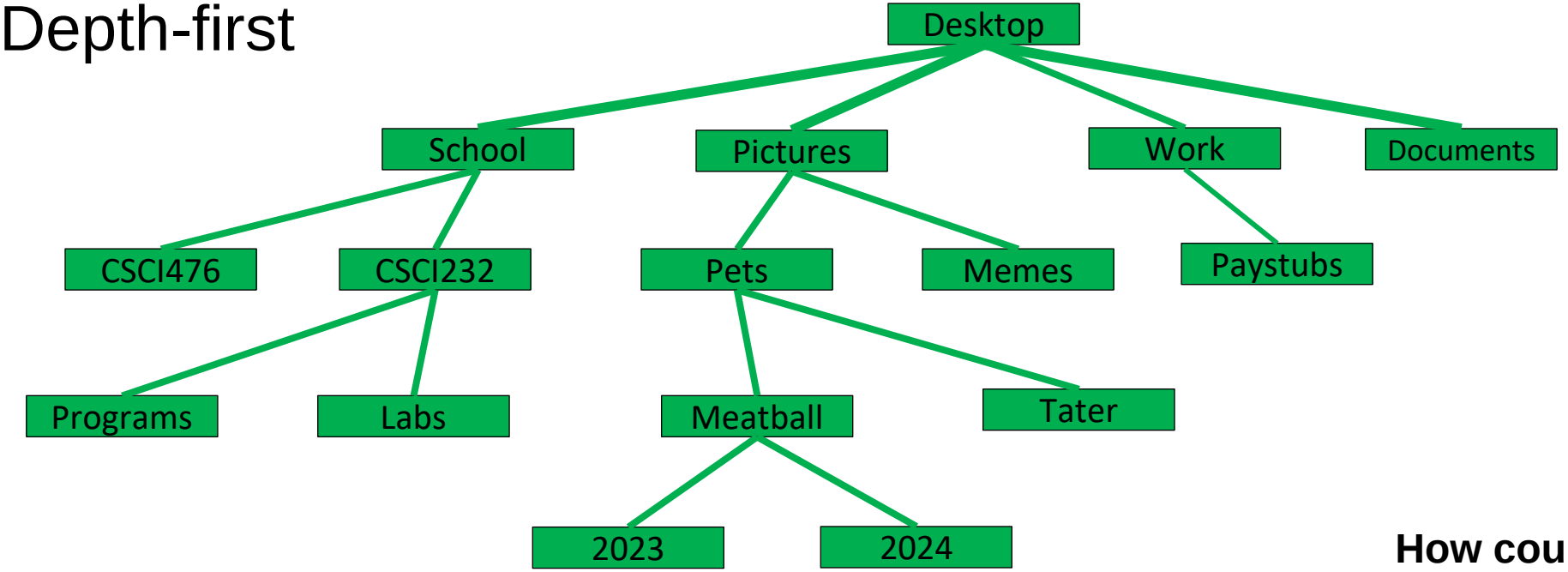
Depth First

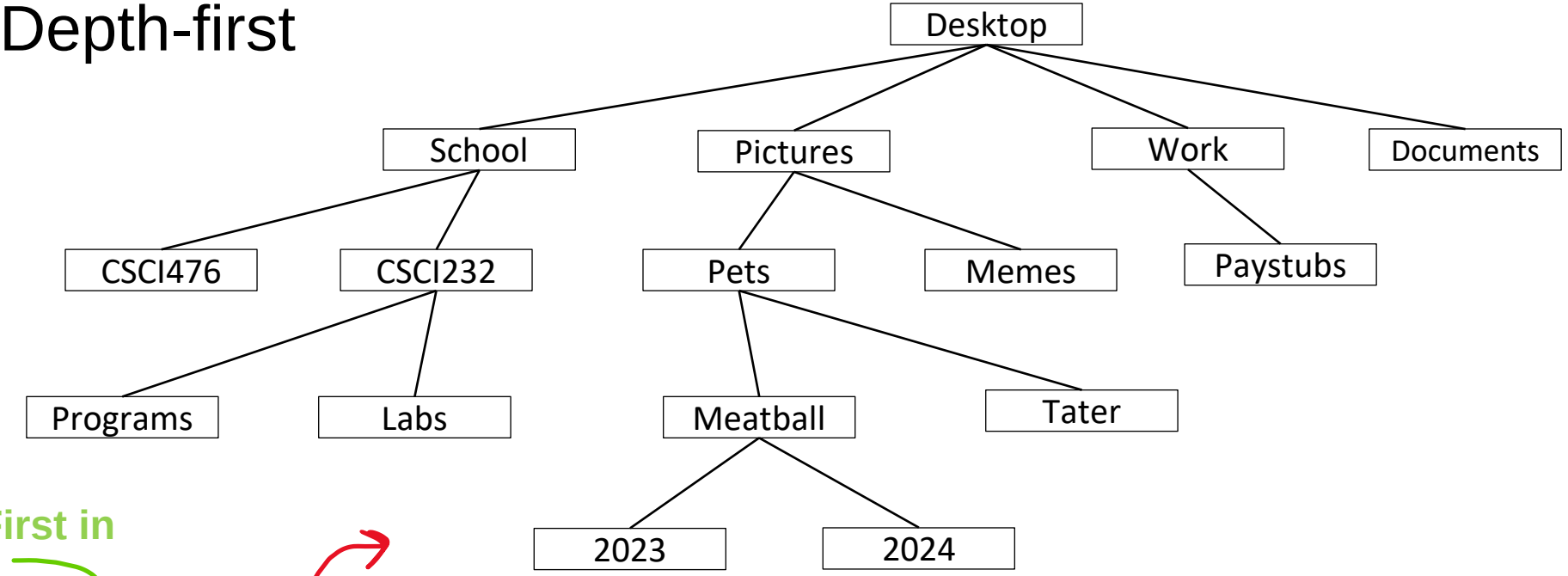
Depth-first



How could we implement this?

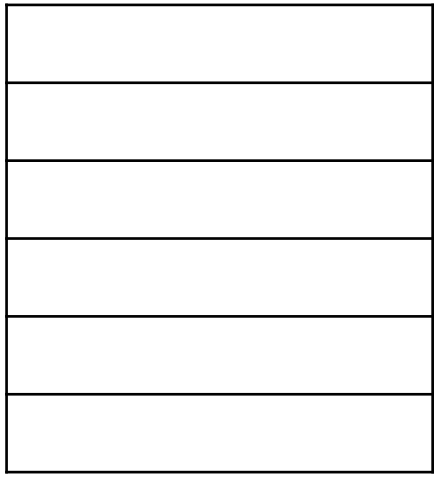
1. Go all the way down the “first” leaf
2. Backtrack until unvisited child is encountered
3. Repeat

Depth-first



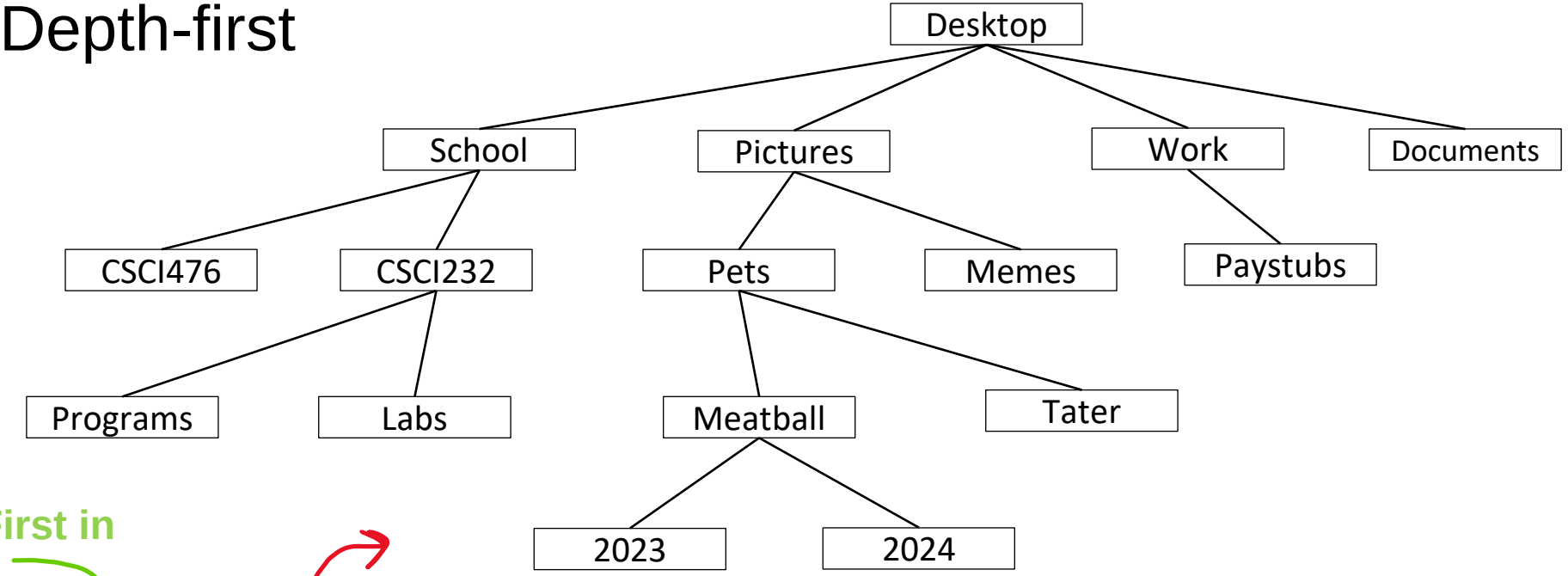
First in

Last out



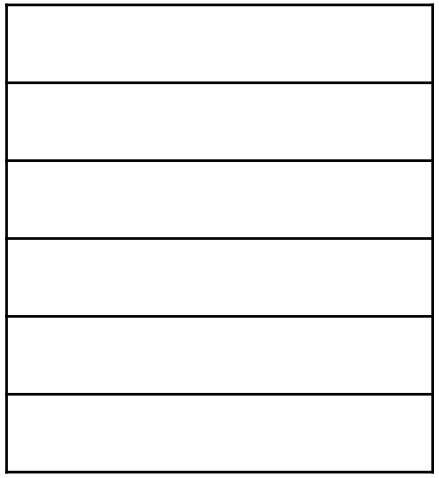
Stack

Depth-first



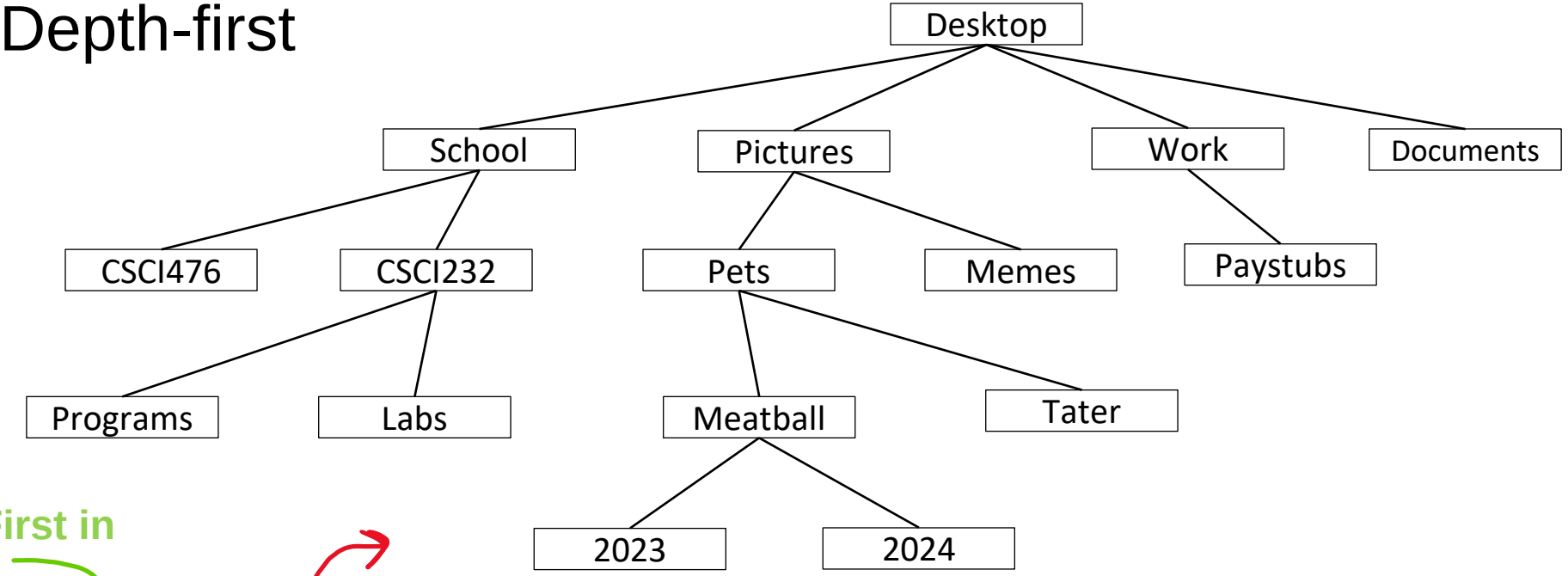
First in

Last out



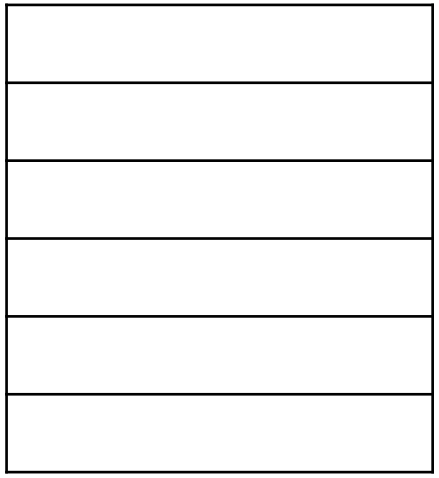
Every time we “visit” a node we:

Depth-first



First in

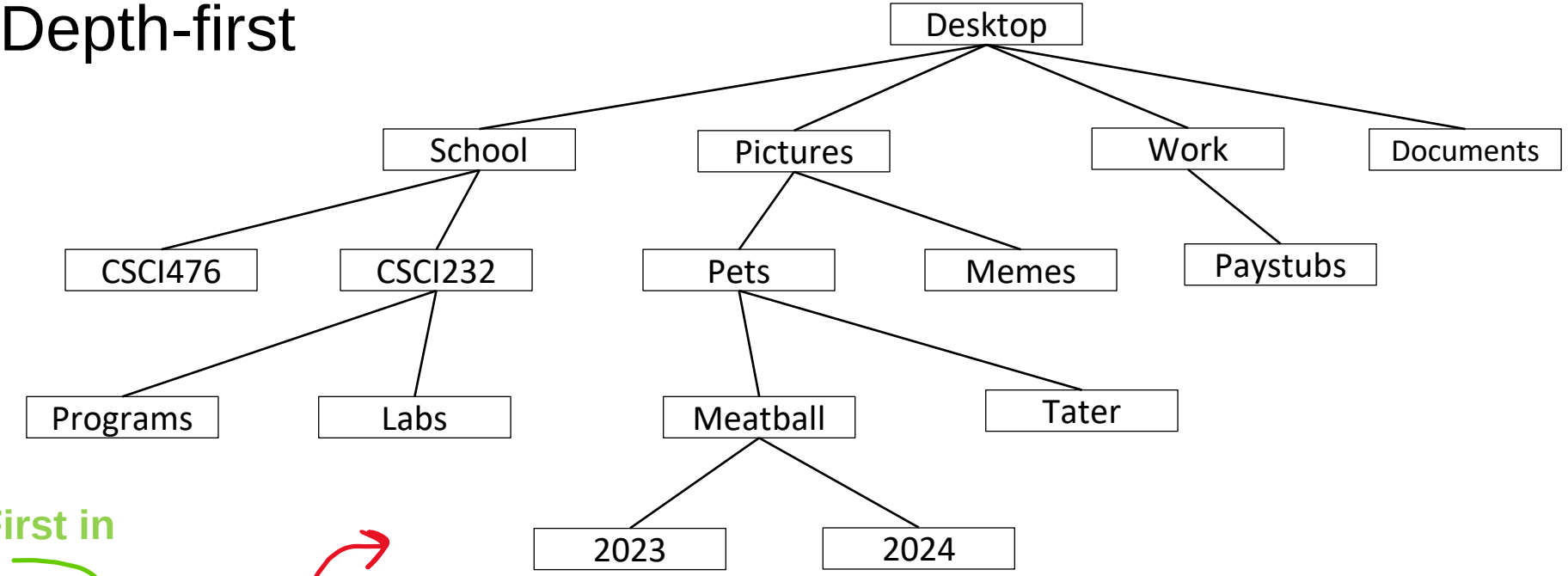
Last out



Every time we “visit” a node we:

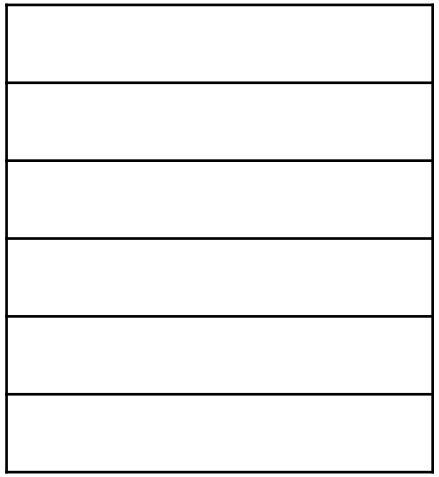
1. Remove node from stack

Depth-first



First in

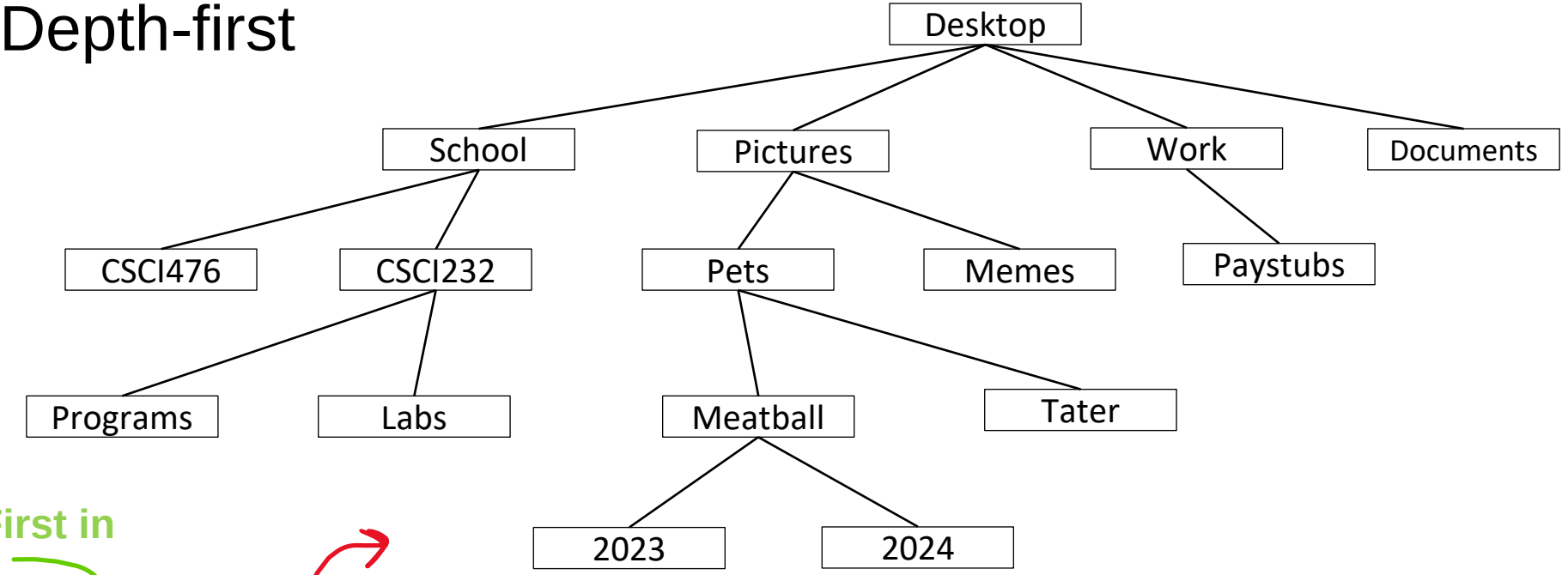
Last out



Every time we “visit” a node we:

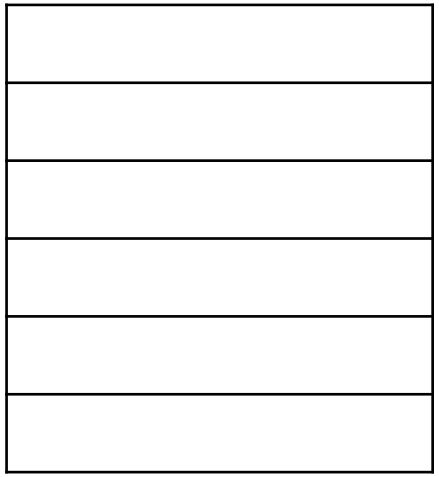
1. Remove node from stack
2. Execute the action (print, compare, etc)

Depth-first



First in

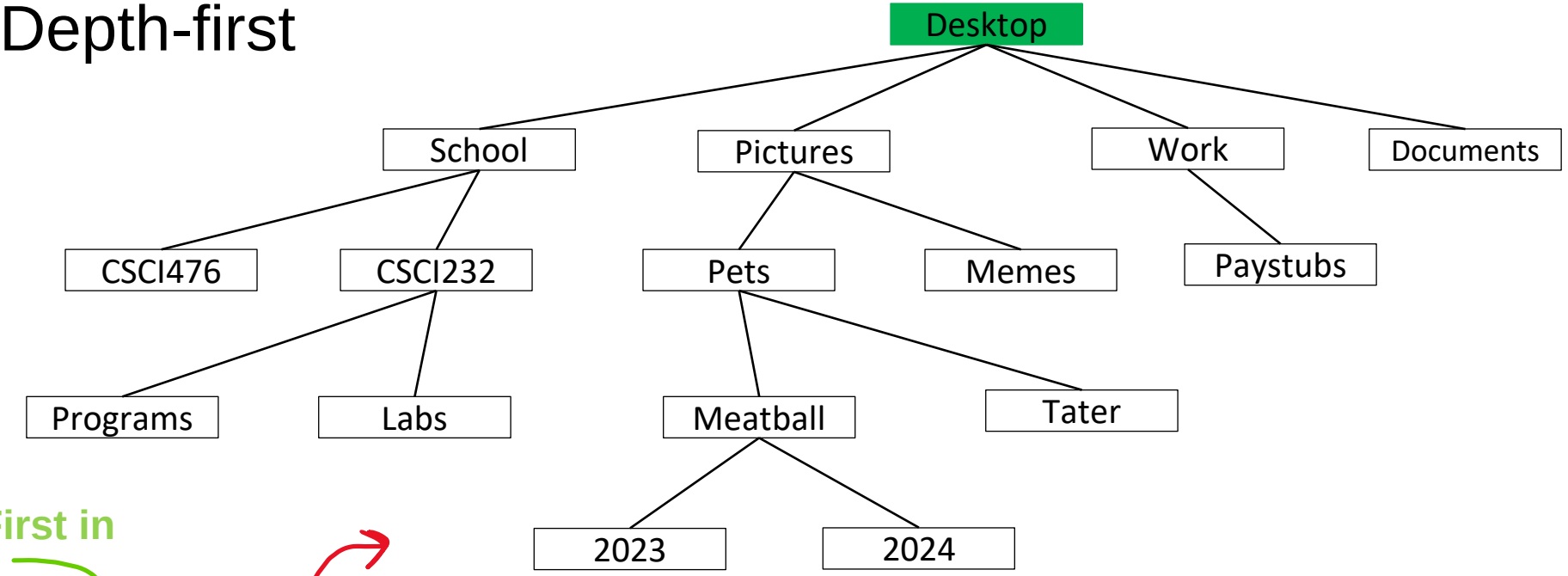
Last out



Every time we “visit” a node we:

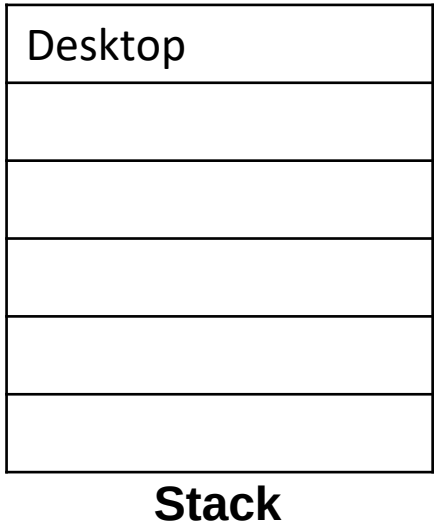
1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



First in

Last out

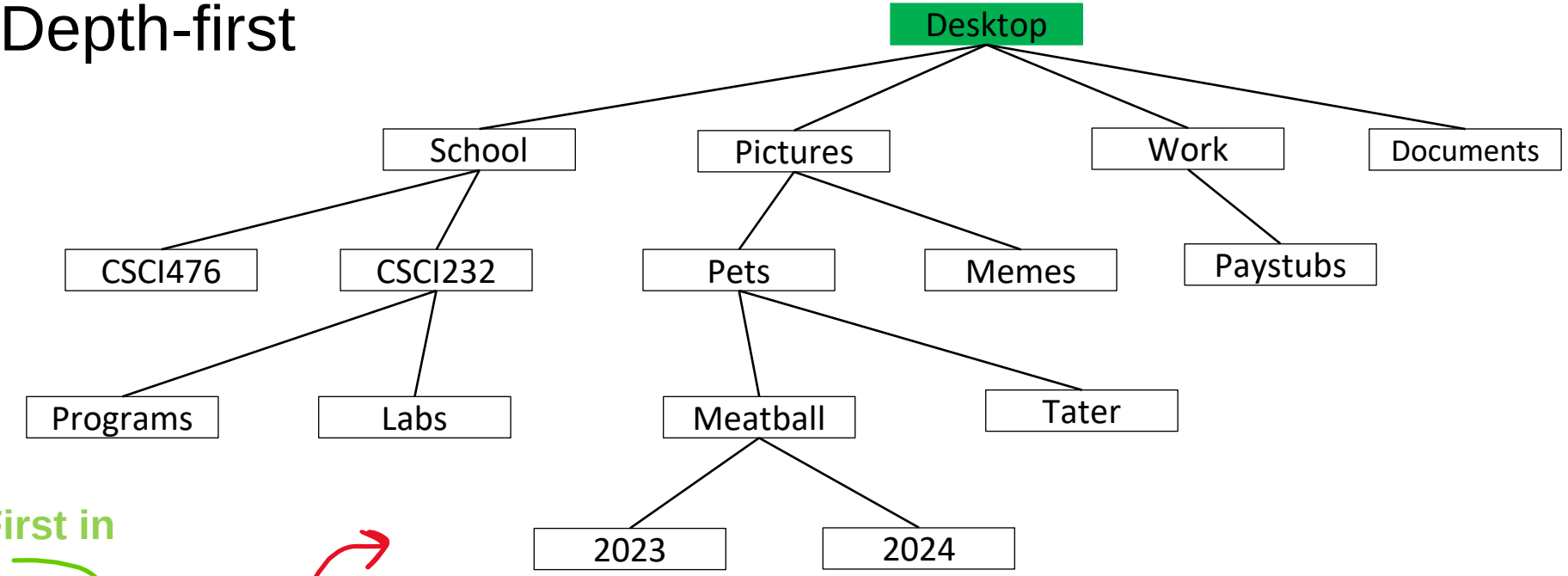


Stack

Every time we “visit” a node we:

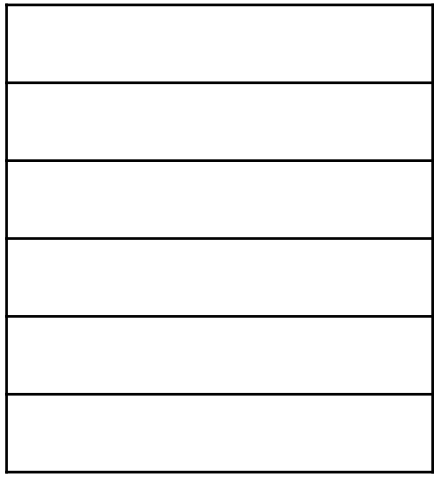
1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



First in

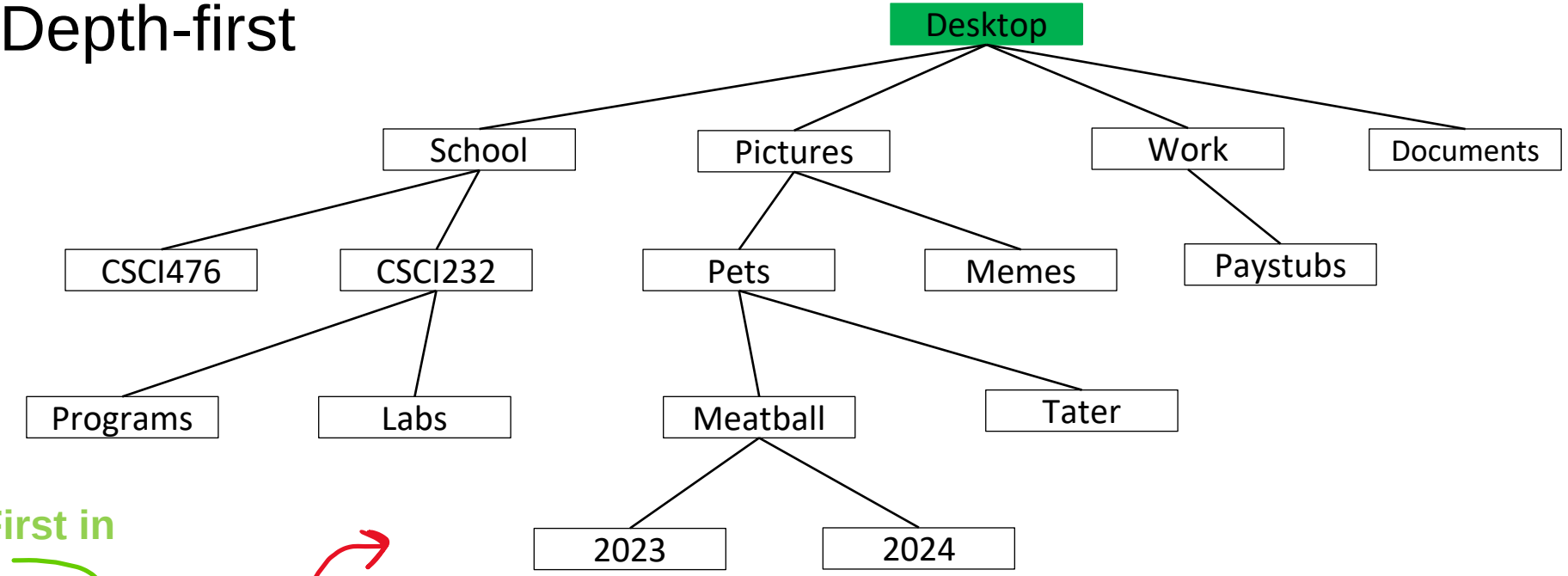
Last out



Every time we “visit” a node we:

1. Remove node from stack Desktop
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first

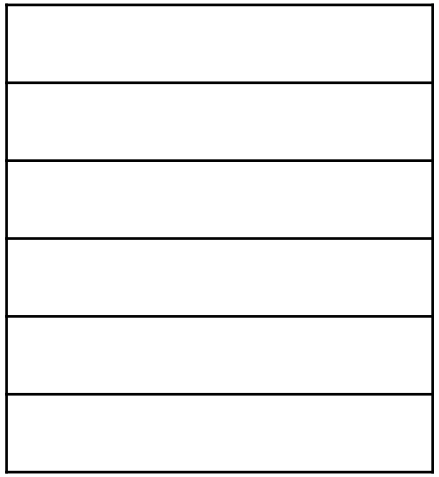


Output

Desktop

First in

Last out

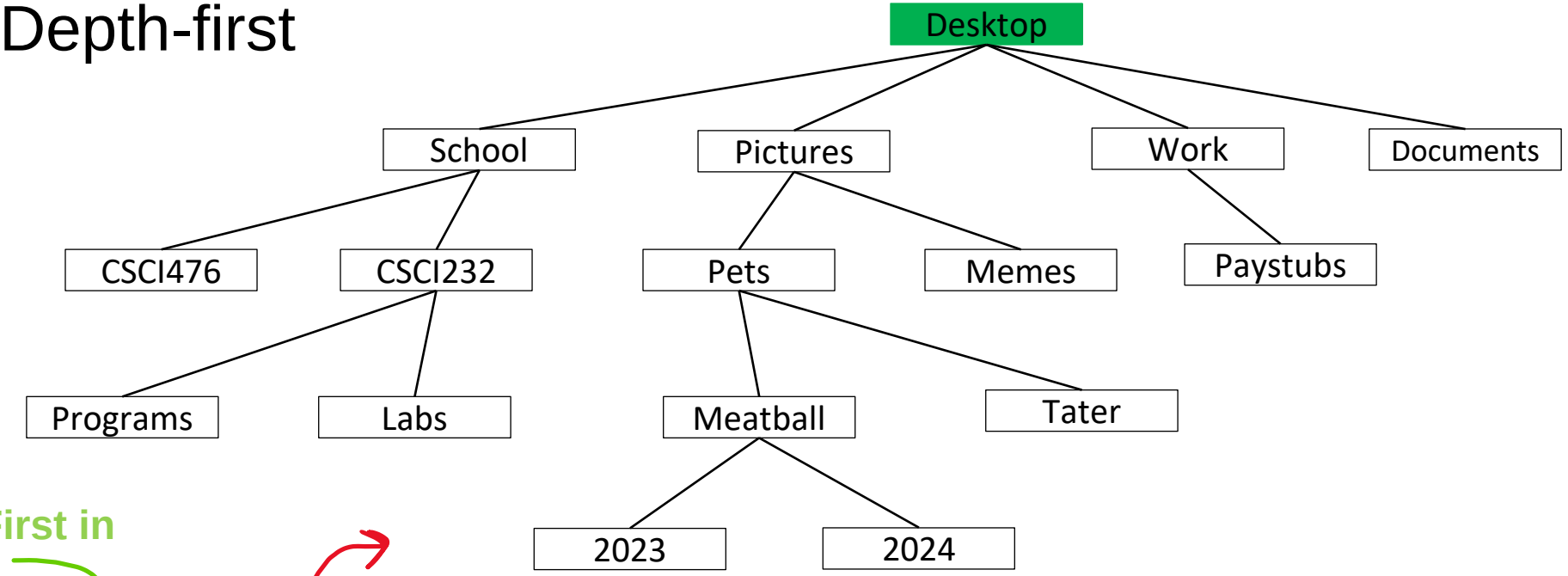


Stack

Every time we "visit" a node we:

1. Remove node from stack Desktop
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

Desktop

First in

Last out

!!

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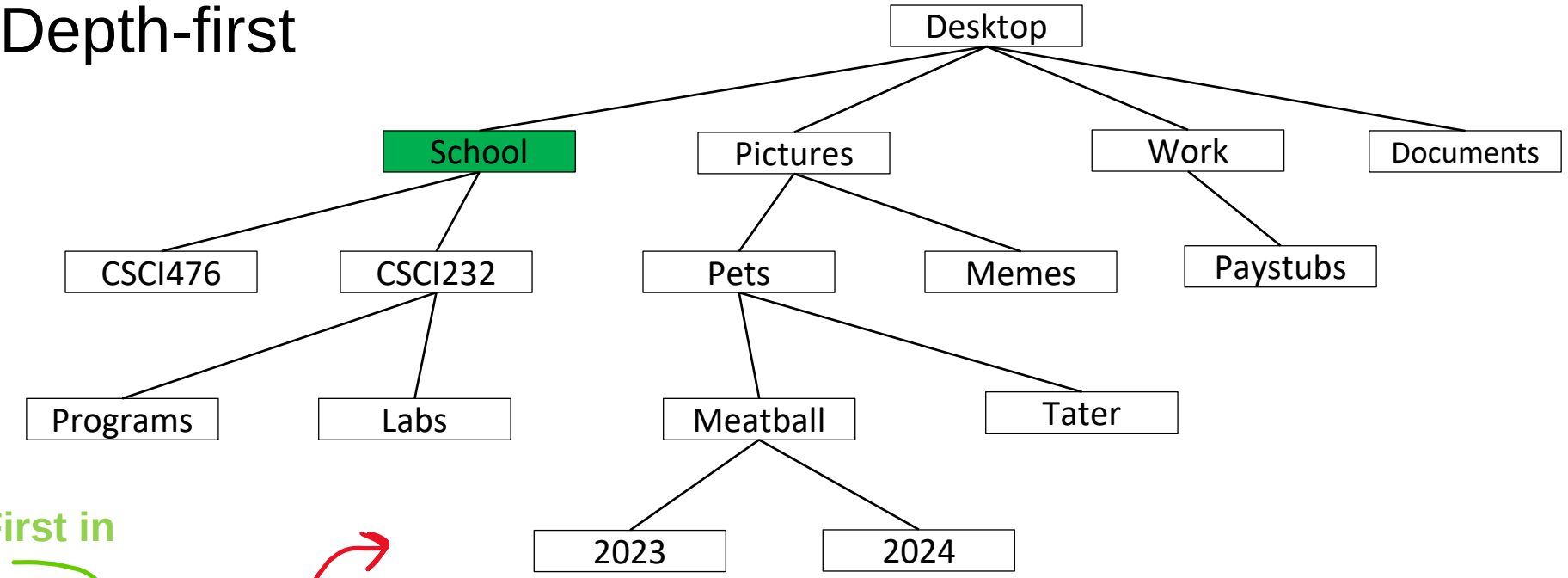
Stack

Every time we "visit" a node we:

1. Remove node from stack Desktop
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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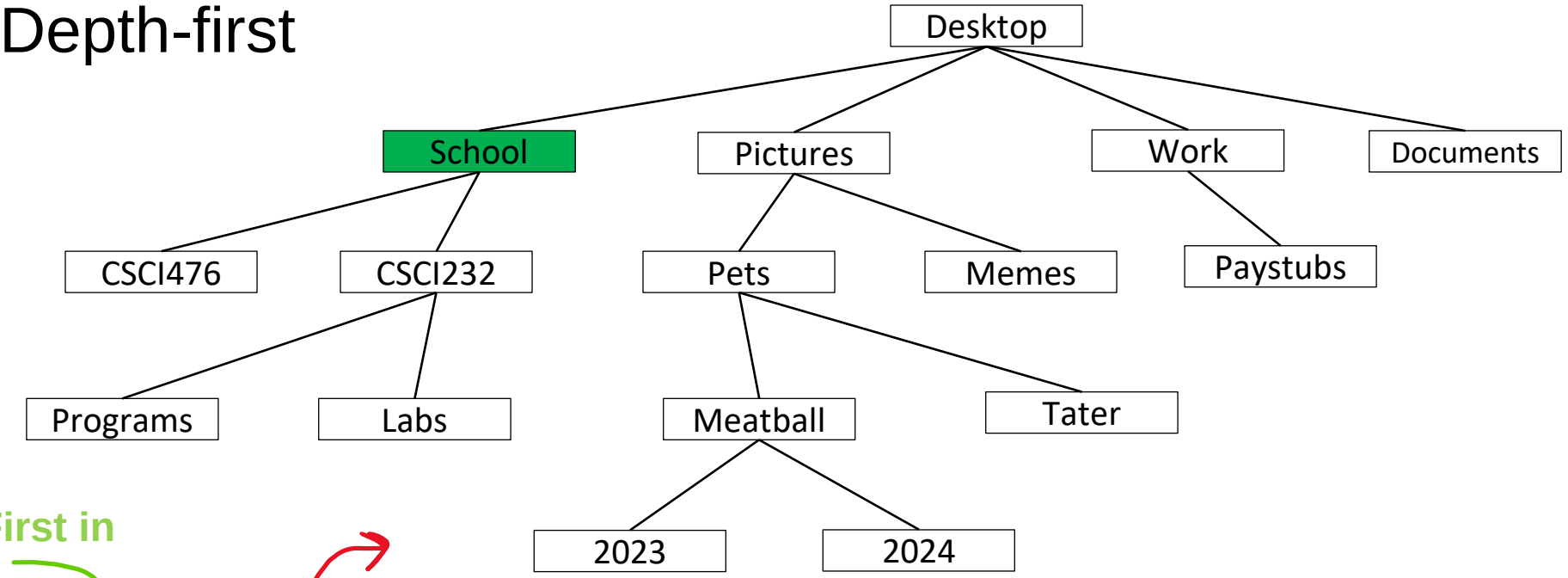
Stack

Every time we "visit" a node we:

1. Remove node from stack School
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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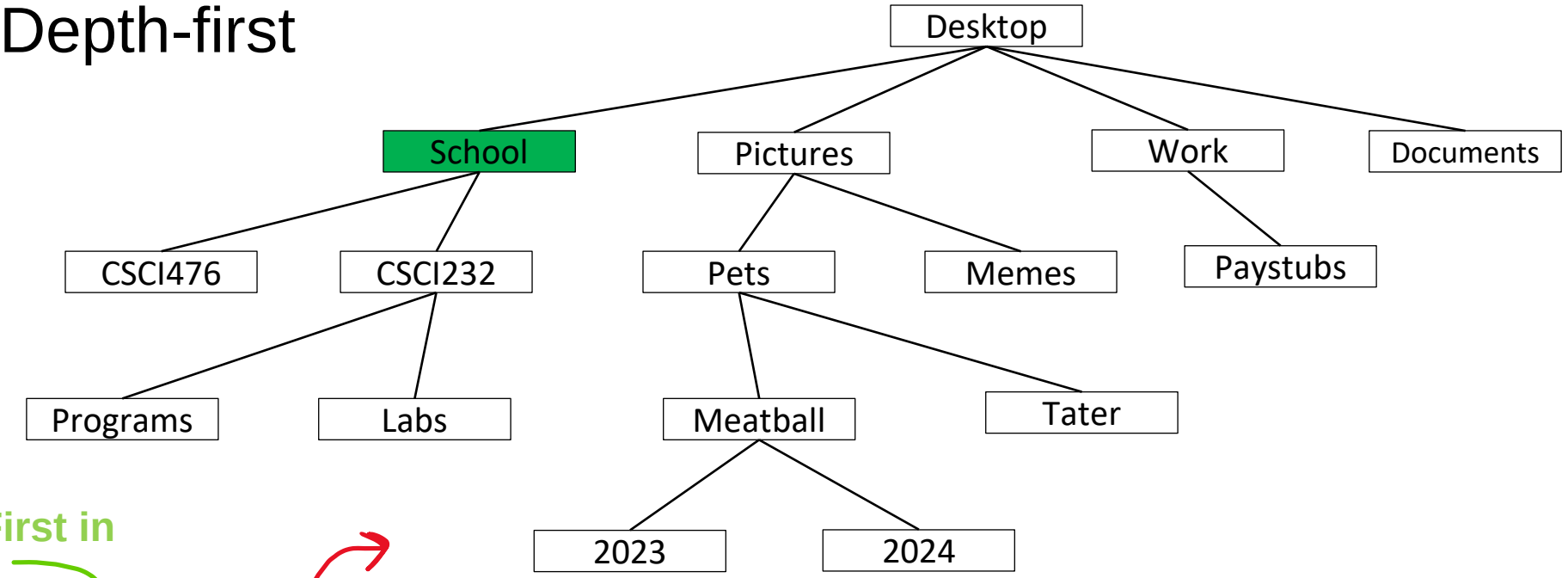
Stack

Every time we “visit” a node we:

1. Remove node from stack School
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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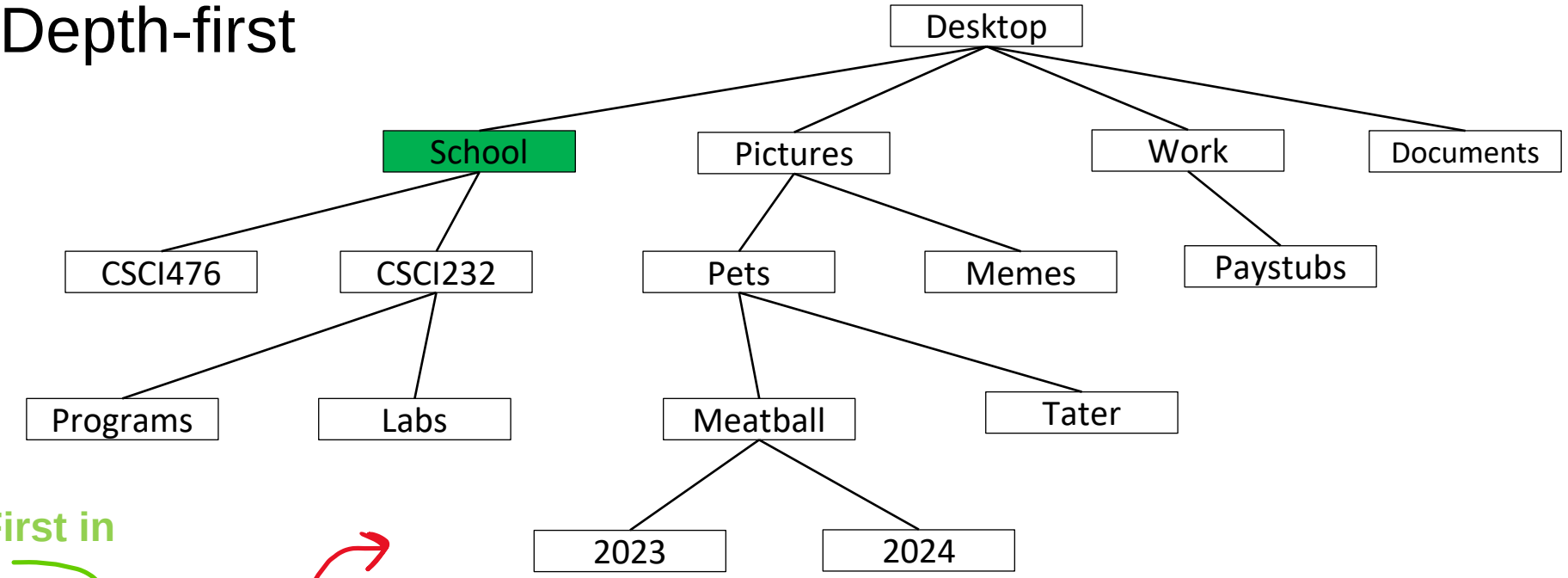
Stack

Every time we "visit" a node we:

1. Remove node from stack School
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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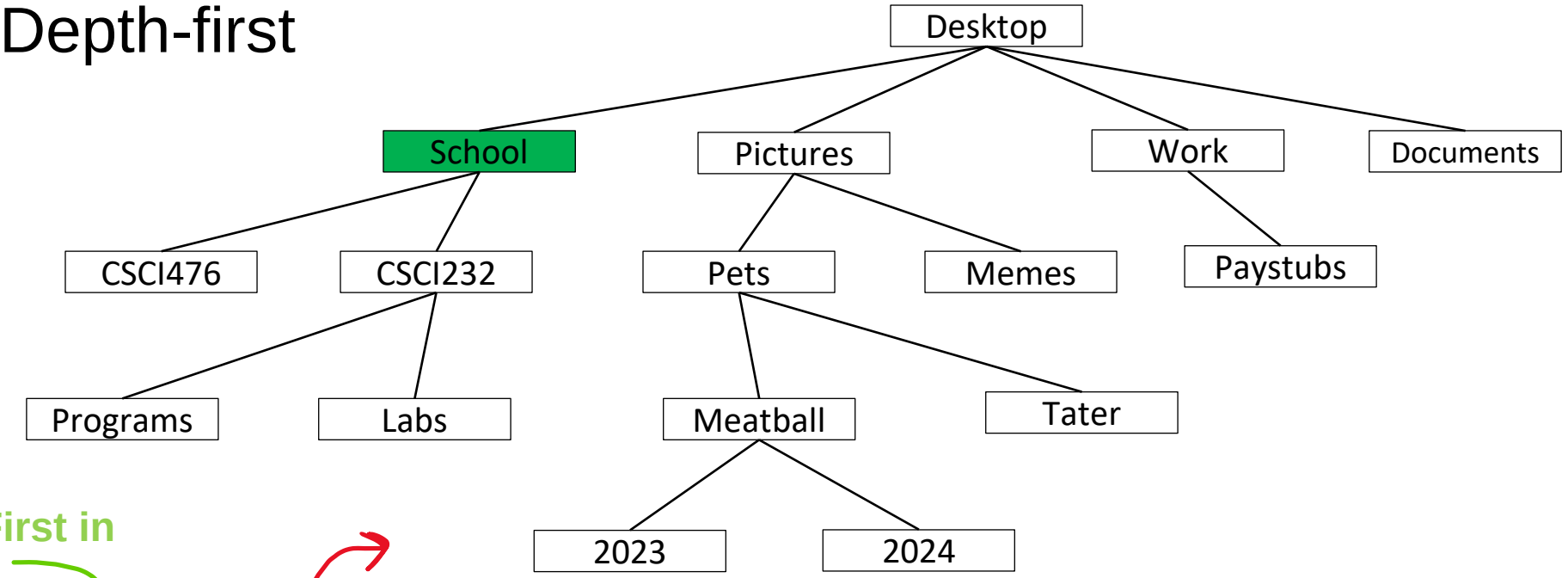
Stack

Every time we "visit" a node we:

1. Remove node from stack School
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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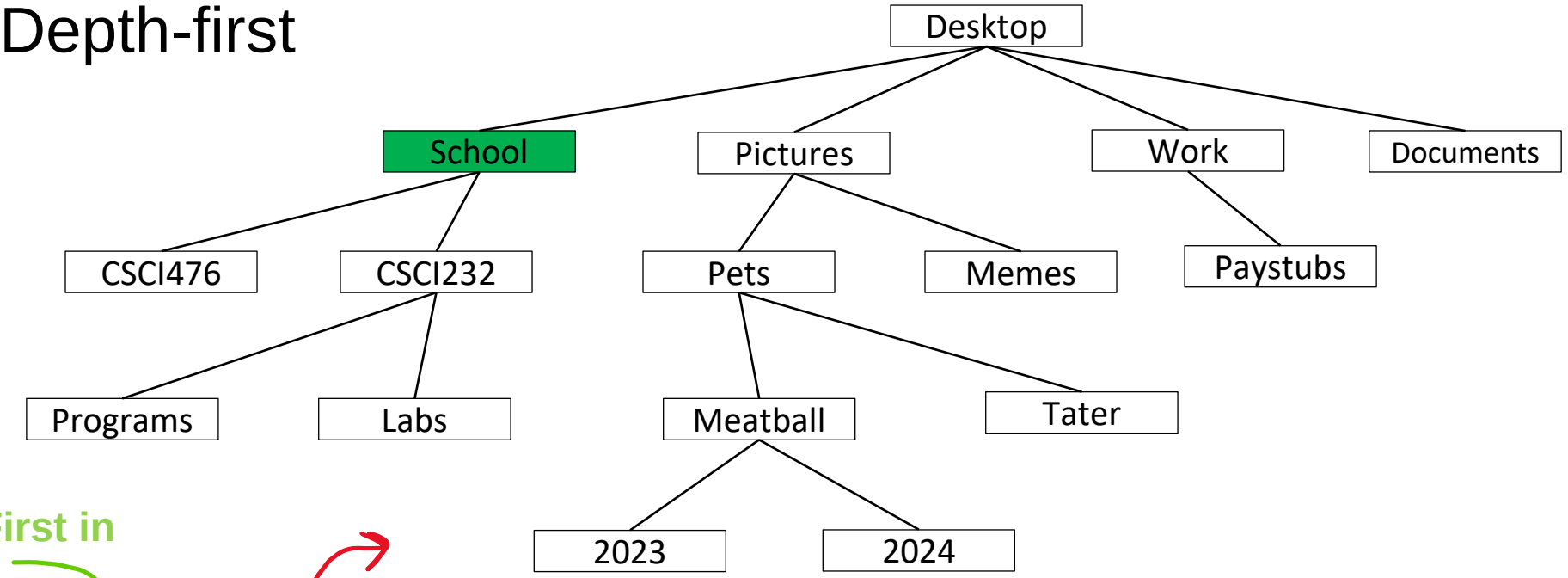
Stack

Every time we "visit" a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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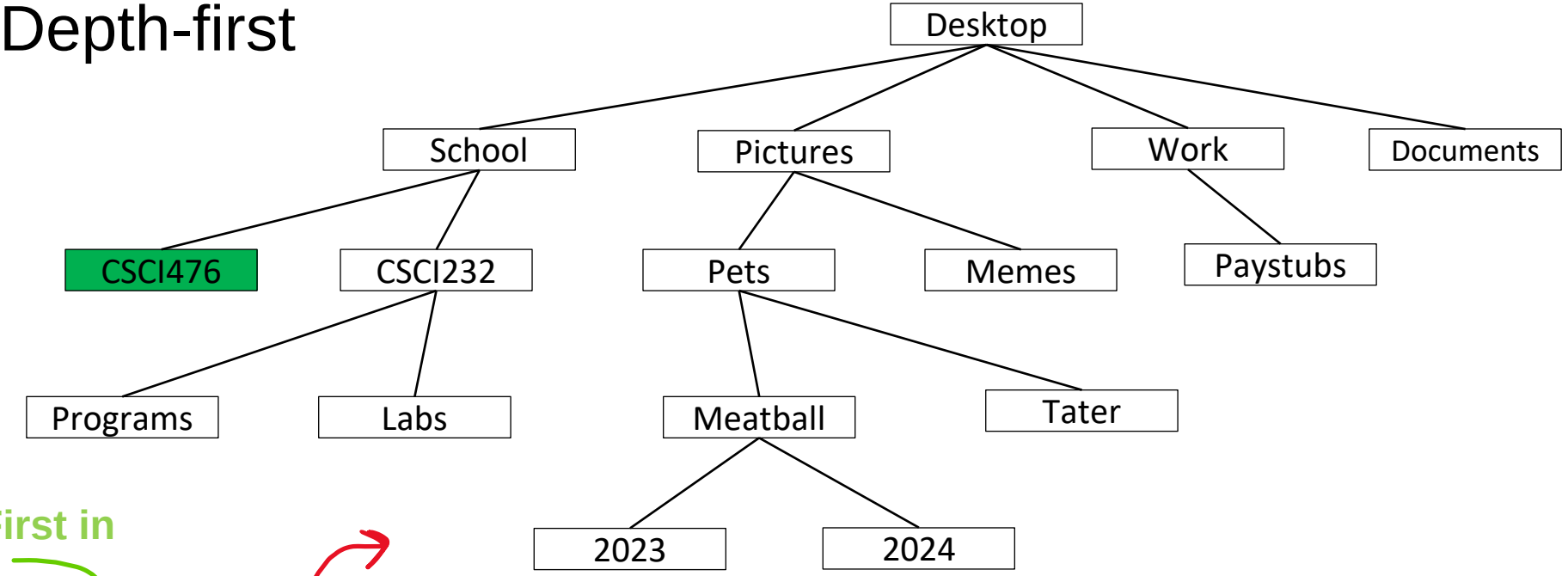
Stack

Every time we "visit" a node we:

1. Remove node from stack CSCI476
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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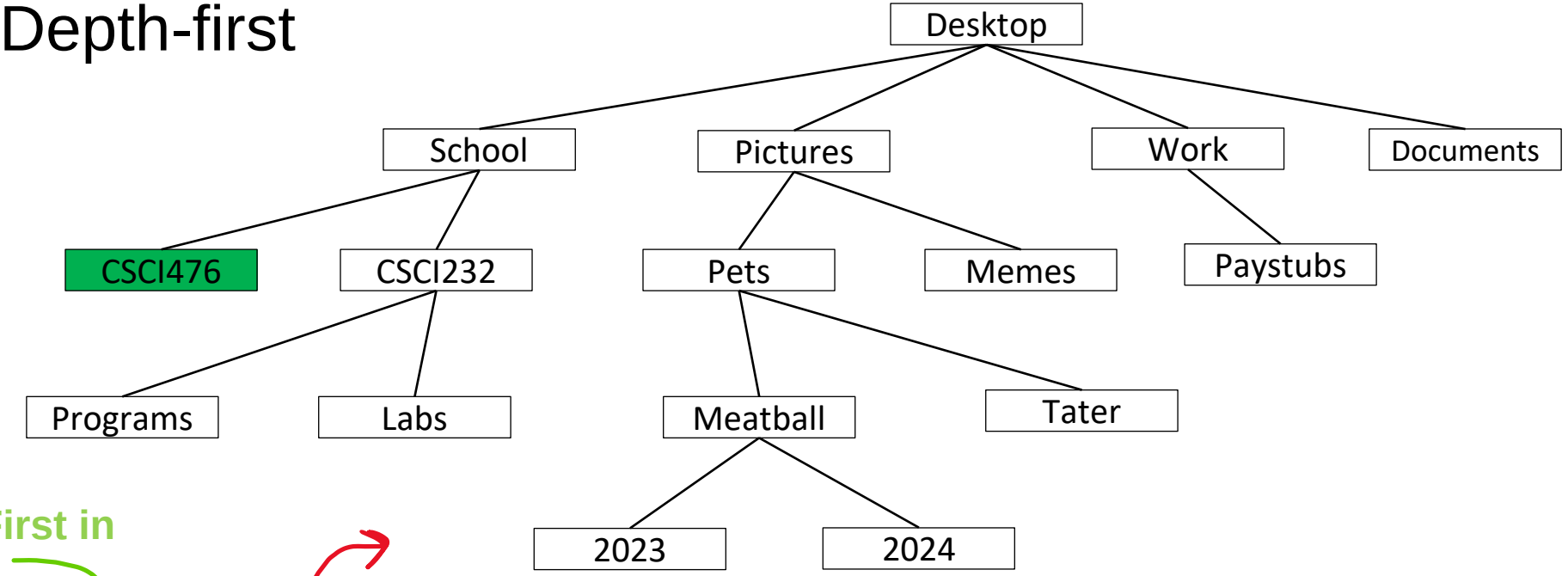
Stack

Every time we “visit” a node we:

1. Remove node from stack CSCI476
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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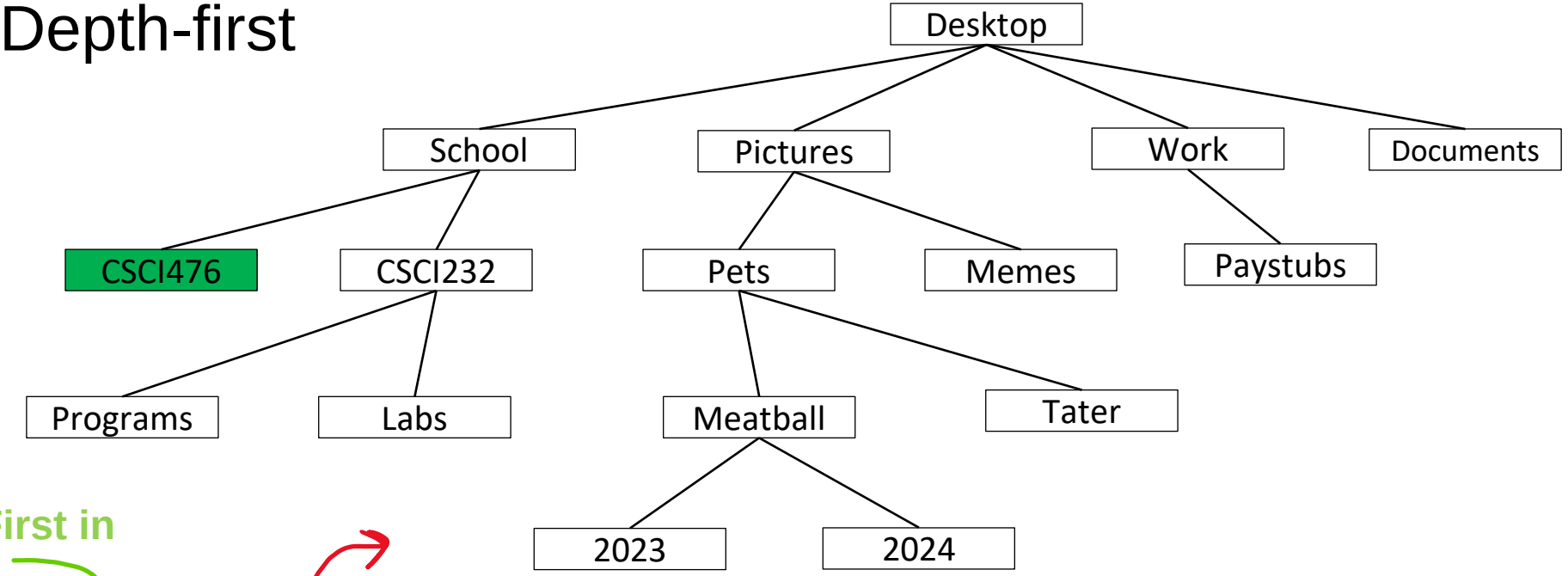
Stack

Every time we "visit" a node we:

1. Remove node from stack CSCI476
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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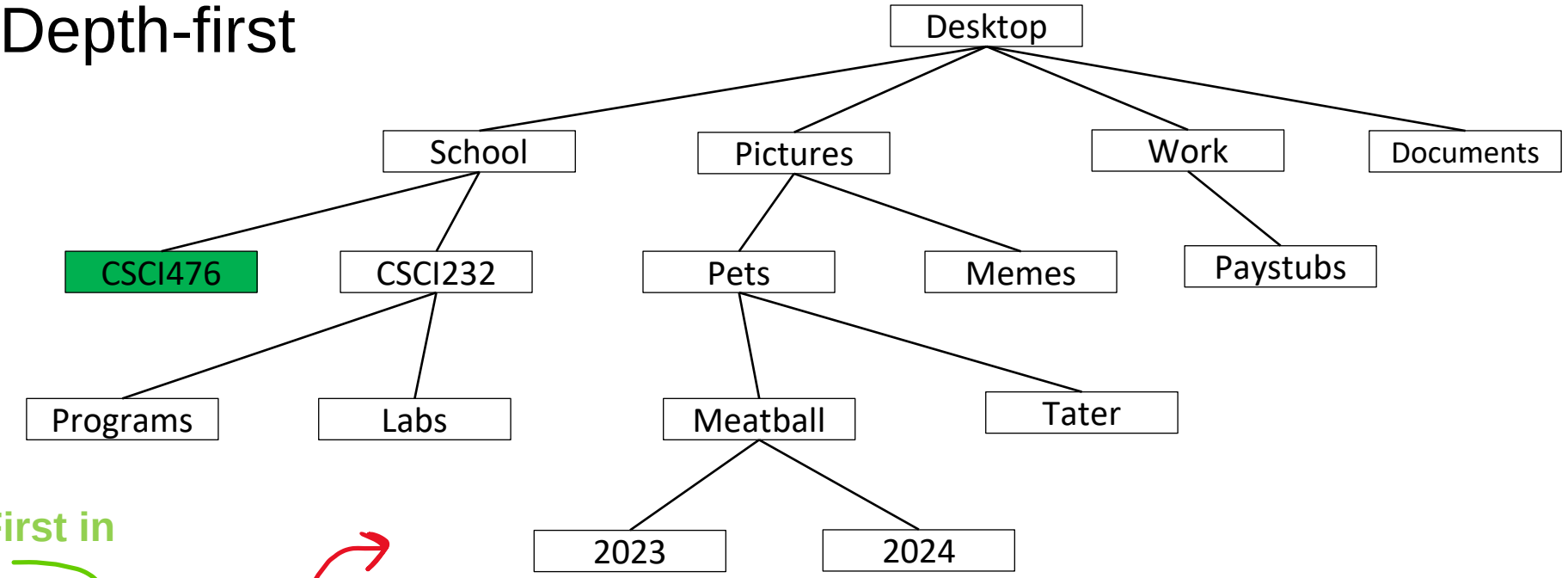
Stack

Every time we "visit" a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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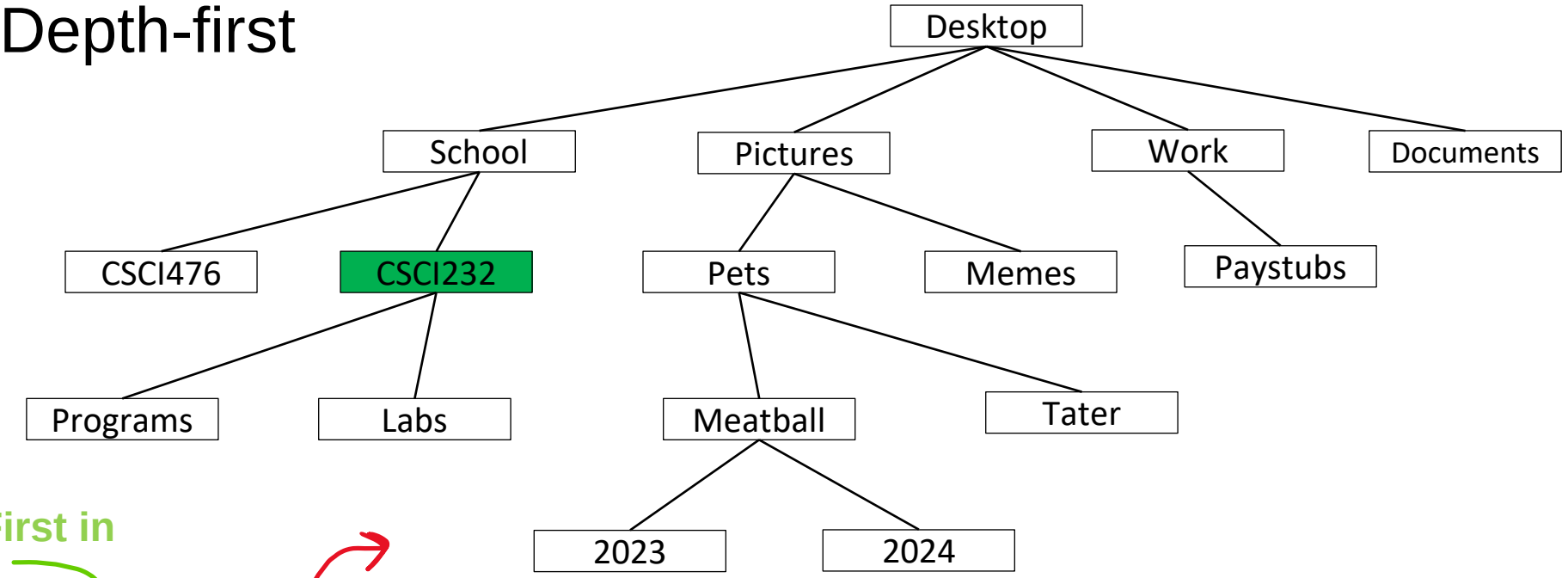
Stack

Every time we "visit" a node we:

1. Remove node from stack CSCI232
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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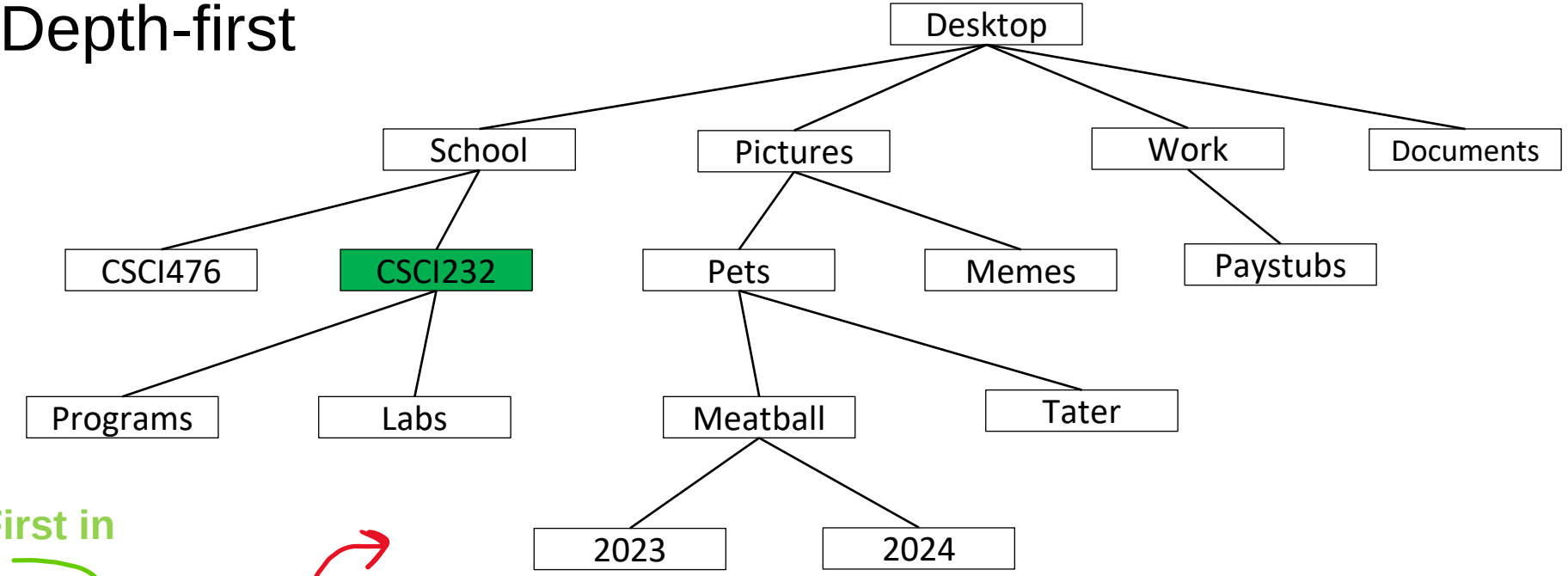
Stack

Every time we "visit" a node we:

1. Remove node from stack CSCI232
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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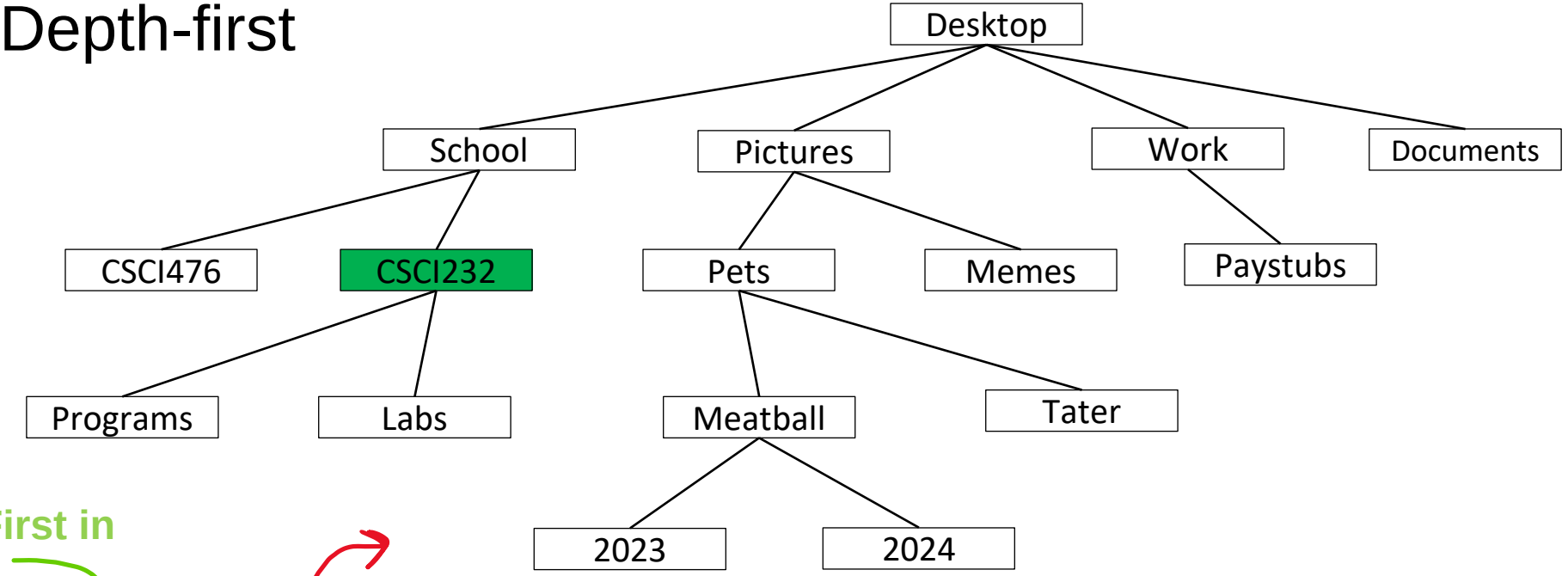
Stack

Every time we "visit" a node we:

1. Remove node from stack CSCI232
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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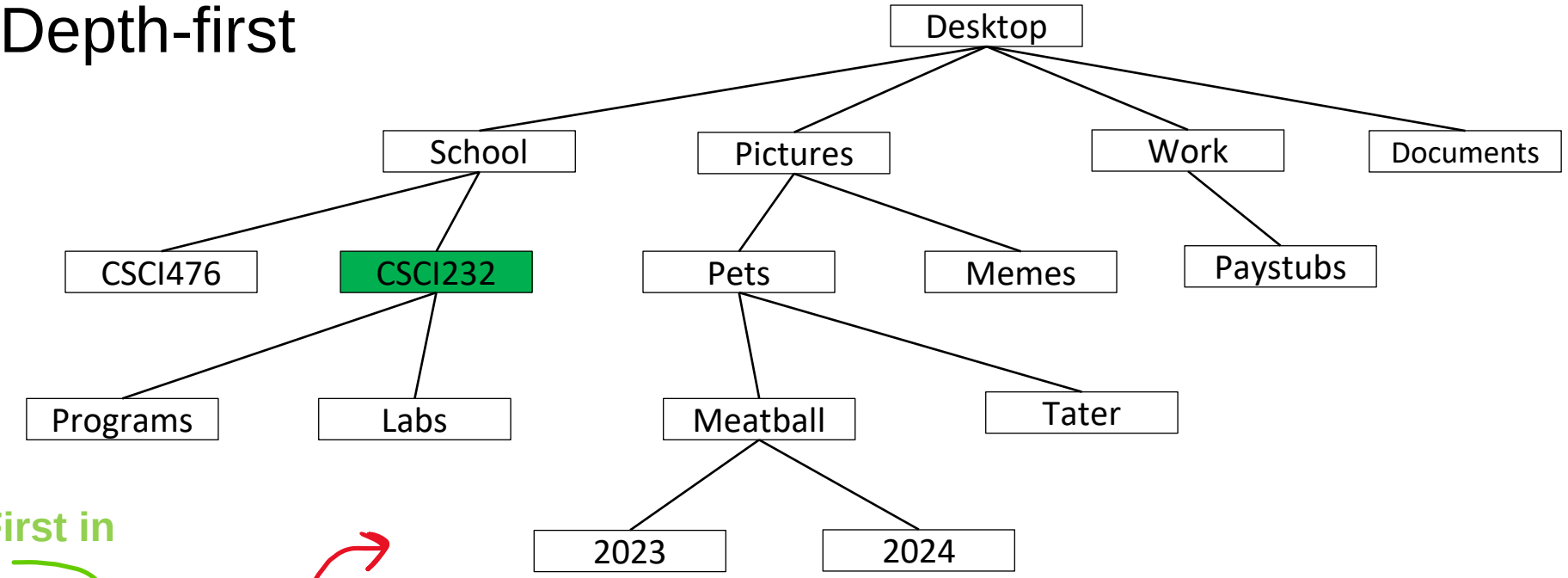
Stack

Every time we "visit" a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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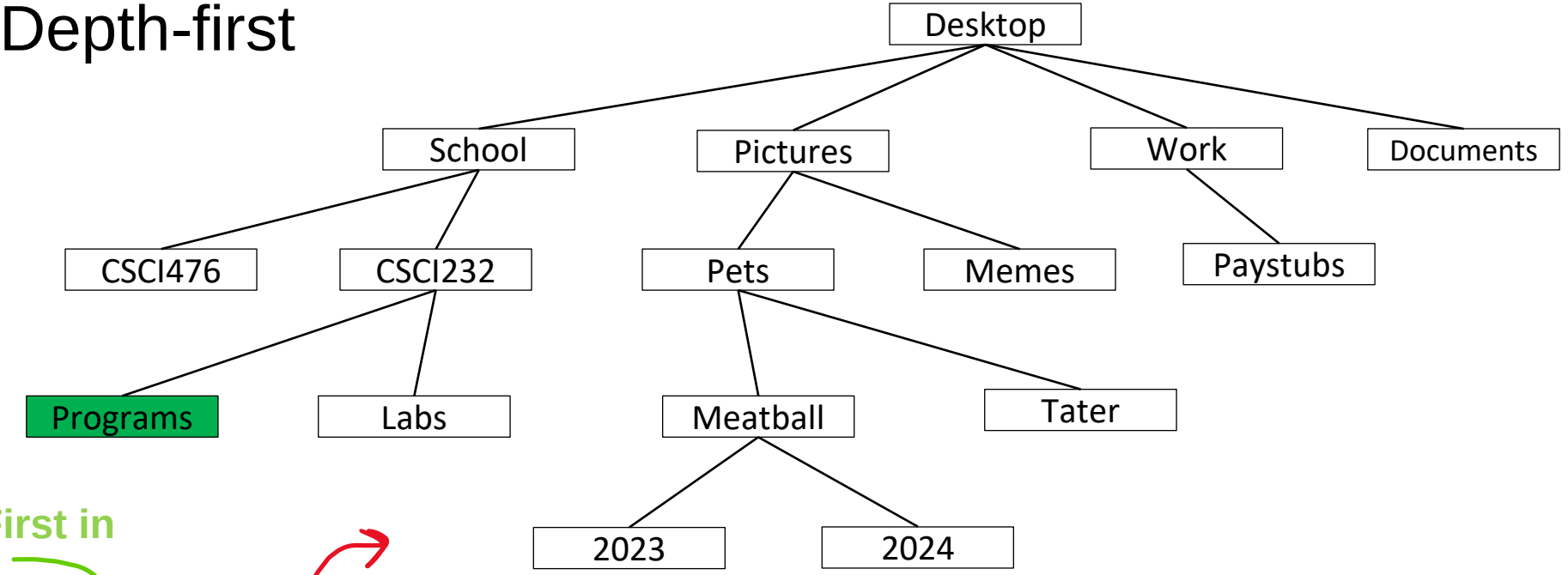
Stack

Every time we "visit" a node we:

1. Remove node from stack Programs
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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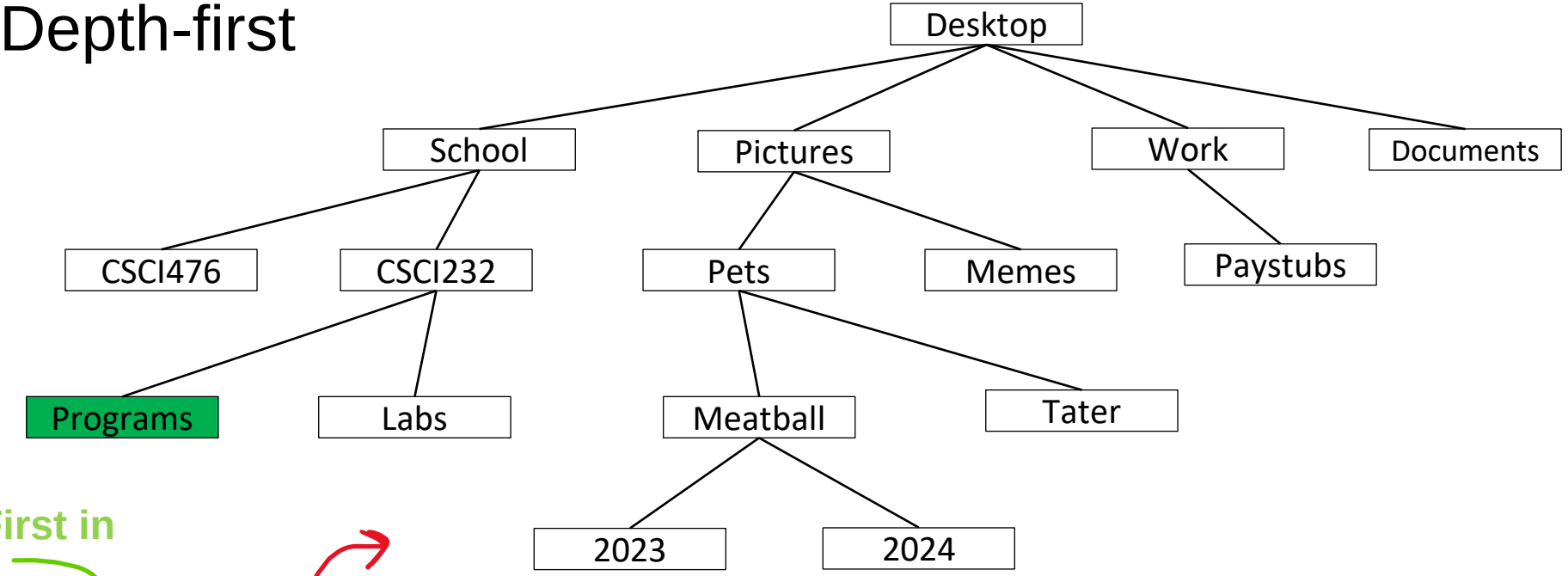
Stack

Every time we "visit" a node we:

1. Remove node from stack Programs
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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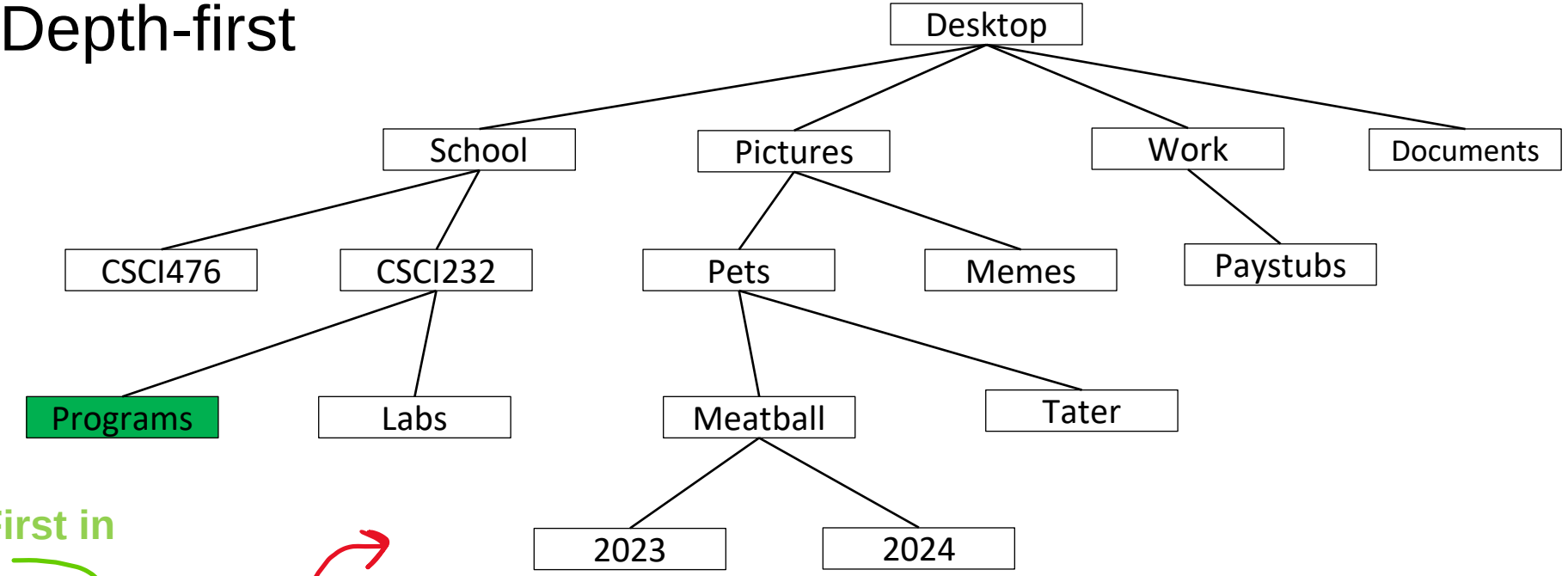
Stack

Every time we "visit" a node we:

1. Remove node from stack Programs
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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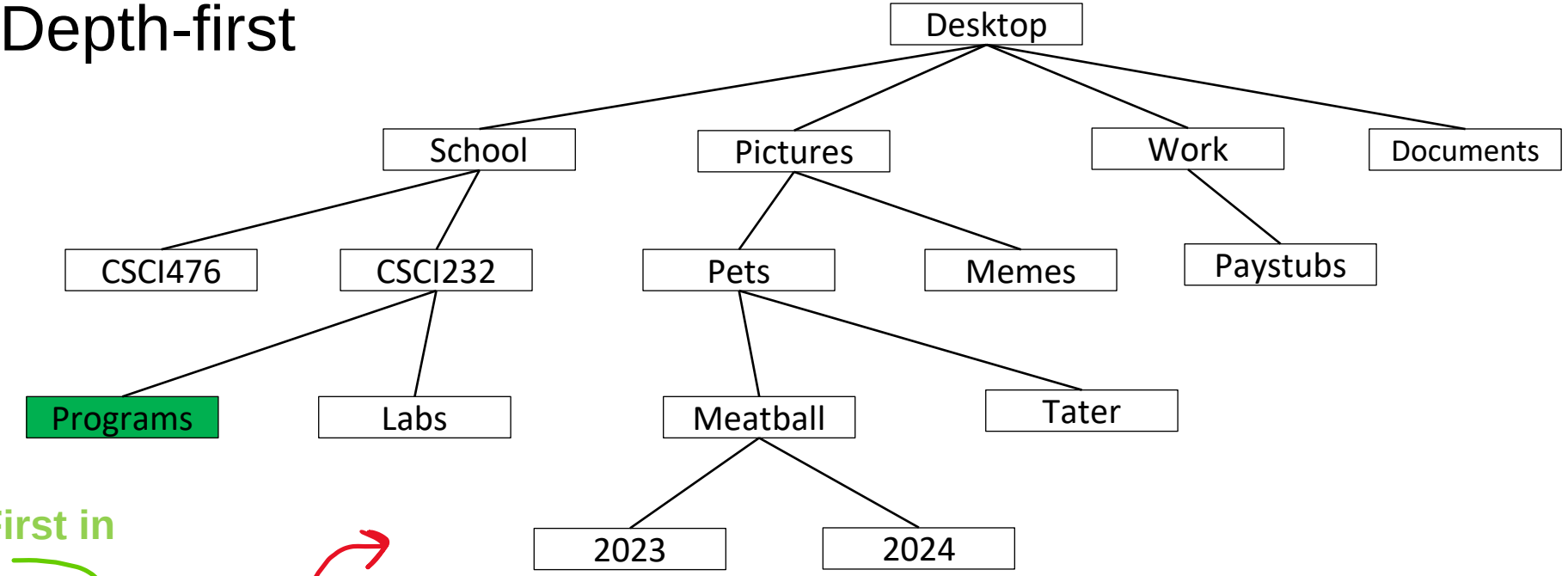
Stack

Every time we "visit" a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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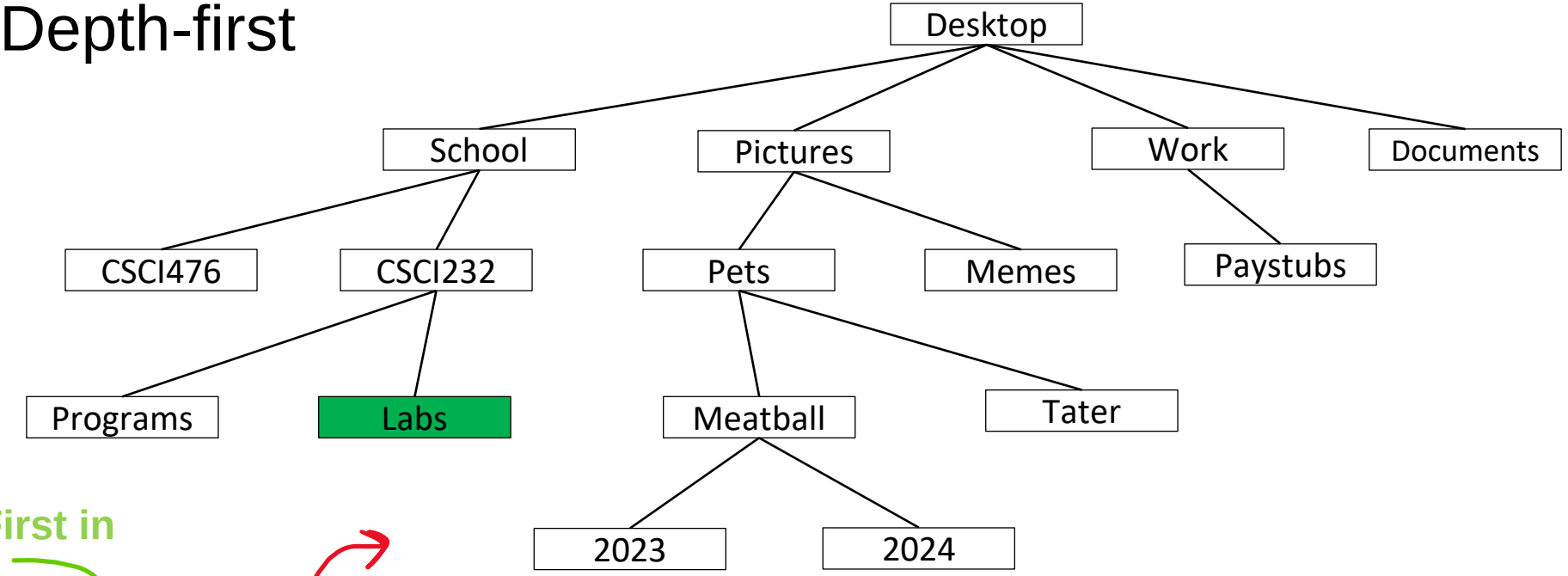
Stack

Every time we "visit" a node we:

1. Remove node from stack Labs
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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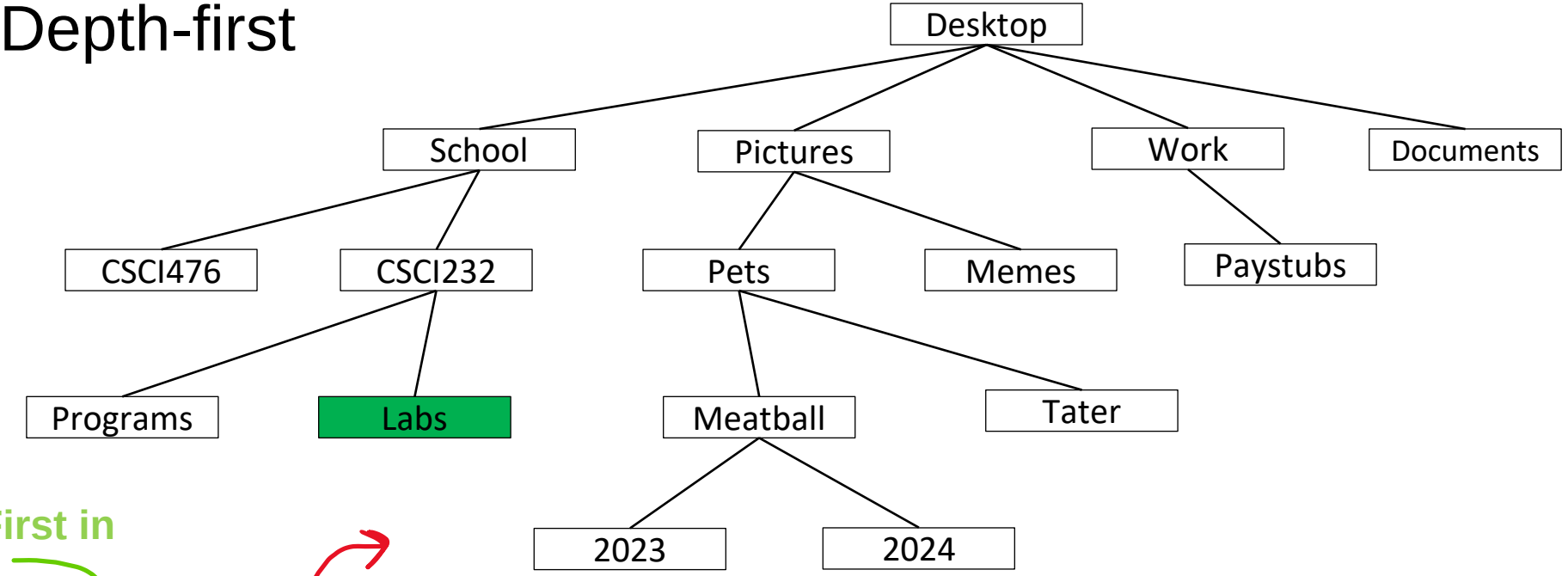
Stack

Every time we "visit" a node we:

1. Remove node from stack Labs
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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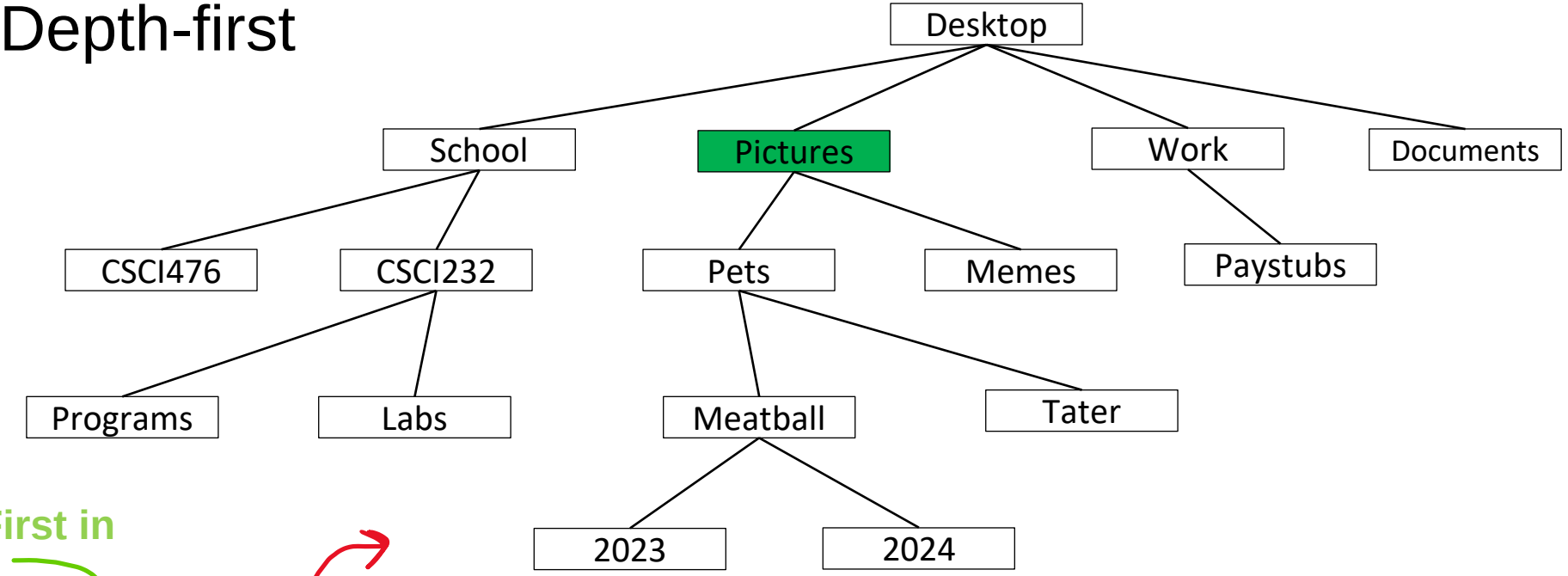
Stack

Every time we "visit" a node we:

1. Remove node from stack Labs
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth-first



Output

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Stack

Every time we "visit" a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

… and so on

Depth First

```
public void depthFirst(){




}
```

Every time we “visit” a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth First

```
public void depthFirst(){

        Stack<Node> stack = new Stack<Node>();









}
```

Every time we “visit” a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth First

```
public void depthFirst(){

        Stack<Node> stack = new Stack<Node>();

        if ( root != null){

                stack.add(root);









    }

}
```

Every time we “visit” a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Start at the root node

Depth First

```
public void depthFirst(){

        Stack<Node> stack = new Stack<Node>();

        if ( root != null){

                stack.add(root);

                while (!stack.isEmpty()){









                }

    }

}
```

Every time we “visit” a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Keep looping as long as we have unvisited nodes in our stack

Depth First

```
public void depthFirst(){

        Stack<Node> stack = new Stack<Node>();

        if ( root != null){

                stack.add(root);

                while (!stack.isEmpty()){
                        Node remove = stack.pop()




                }

    }

}
```

Every time we “visit” a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth First

```
public void depthFirst(){

        Stack<Node> stack = new Stack<Node>();

        if ( root != null){

                stack.add(root);

                while (!stack.isEmpty()){
                        Node remove = stack.pop();
                        System.out.println(……);



                }

    }

}
```

Every time we “visit” a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth First

```
public void depthFirst(){

        Stack<Node> stack = new Stack<Node>();

        if ( root != null){

                stack.add(root);

                while (!stack.isEmpty()){
                        Node remove = stack.pop();
                        System.out.println(……);



                }

    }

}
```

Every time we “visit” a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Depth First

```
public void depthFirst(){

        Stack<Node> stack = new Stack<Node>();

        if ( root != null){

                stack.add(root);

                while (!stack.isEmpty()){
                        Node remove = stack.pop();
                        System.out.println(……);
                        for(Node c: remove.getChildren()){

                        }
                }

    }

}
```

Every time we “visit” a node we:

1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

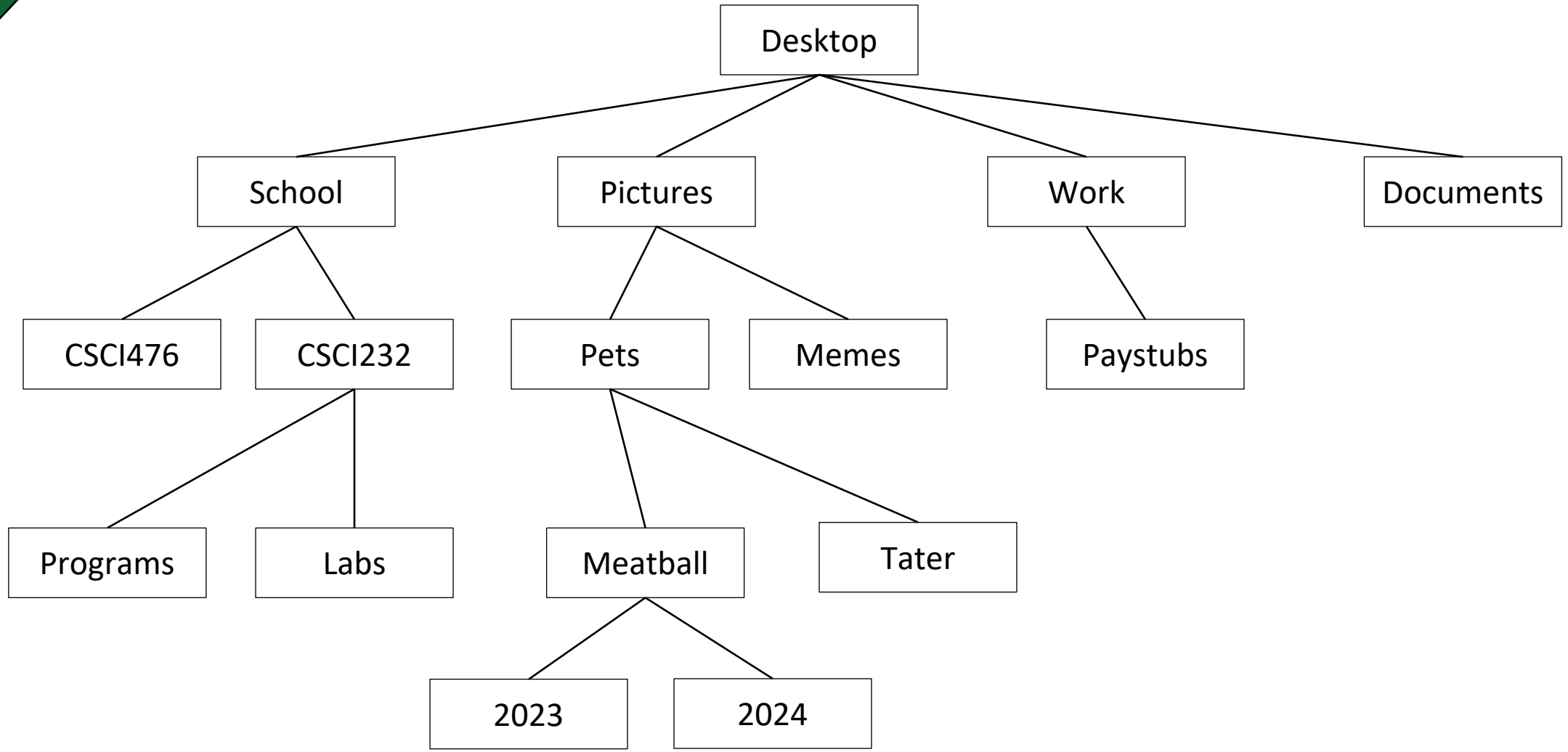
Depth First

```
public void depthFirst(){

        Stack<Node> stack = new Stack<Node>();

        if ( root != null){

                stack.add(root);

                while (!stack.isEmpty()){
                        Node remove = stack.pop();
                        System.out.println(……);
                        for(Node c: remove.getChildren()){
                                stack.push(c);
                        }
                }

    }

}
```

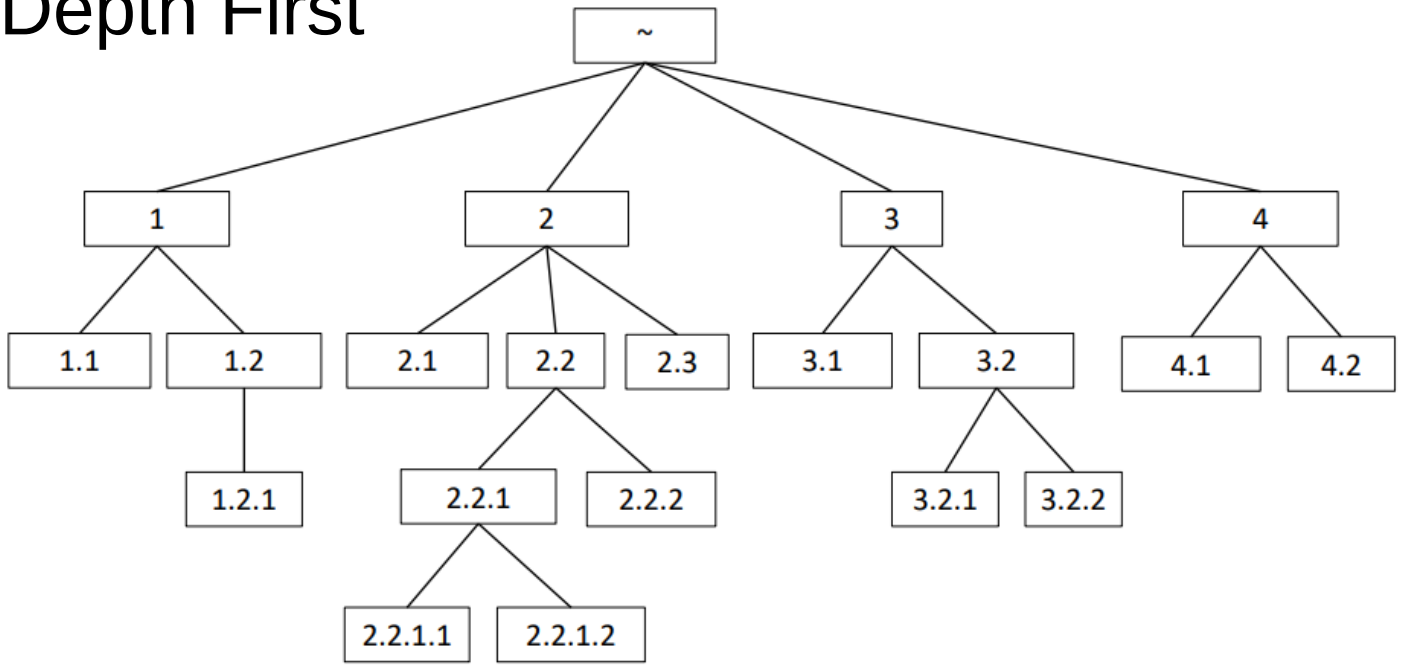
Every time we “visit” a node we:

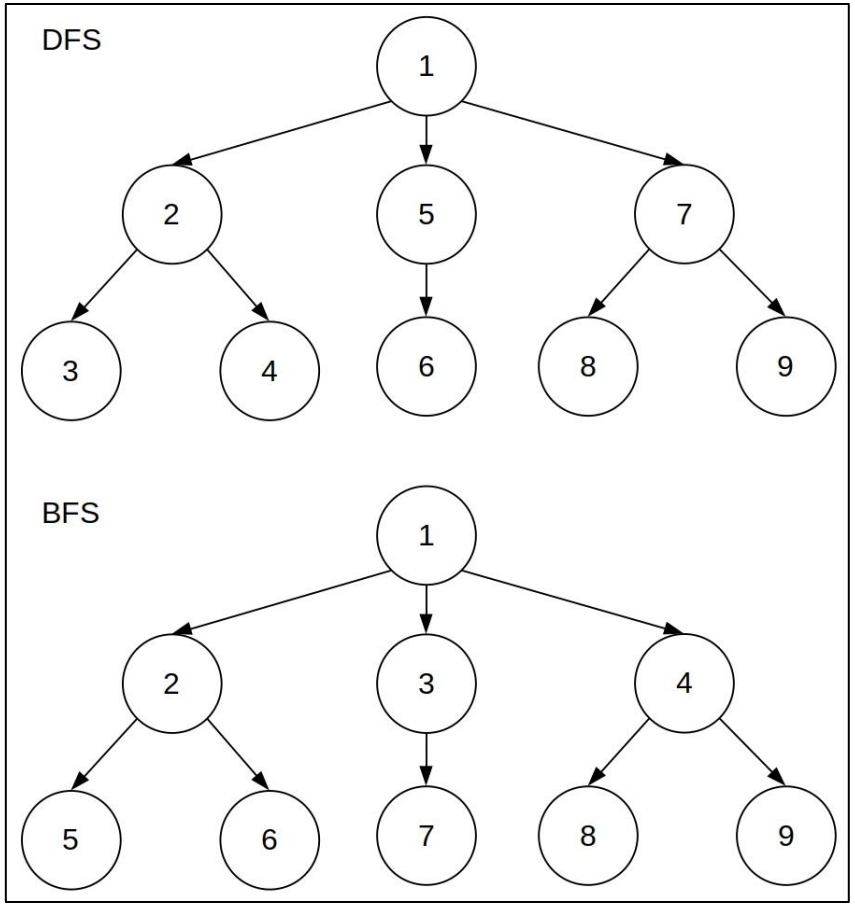
1. Remove node from stack
2. Execute the action (print, compare, etc)
3. Push all children to the stack

Let's code this!


Desktop
School
Pictures
Work
Documents
CSCI476
CSCI232
Pets
Memes
Paystubs
Programs
Labs
Meatball
Tater
2023
2024

Depth First


~
1
2
3
4
1.1
1.2
2.1
2.2
2.3
3.1
3.2
4.1
4.2
1.2.1
2.2.1
2.2.2
3.2.1
3.2.2
2.2.1.1
2.2.1.2


DFS
1
2
5
7
3
4
6
8
9
BFS
1
2
3
4
5
6
7
8
9