Collections, Part Two

Stack

Stack

- A **`Stack`** is a data structure representing a stack of things.
- Objects can be **pushed** on top of the stack or **popped** from the top of the stack.
- No other objects in the stack are visible.
- Example: Function calls

Stack

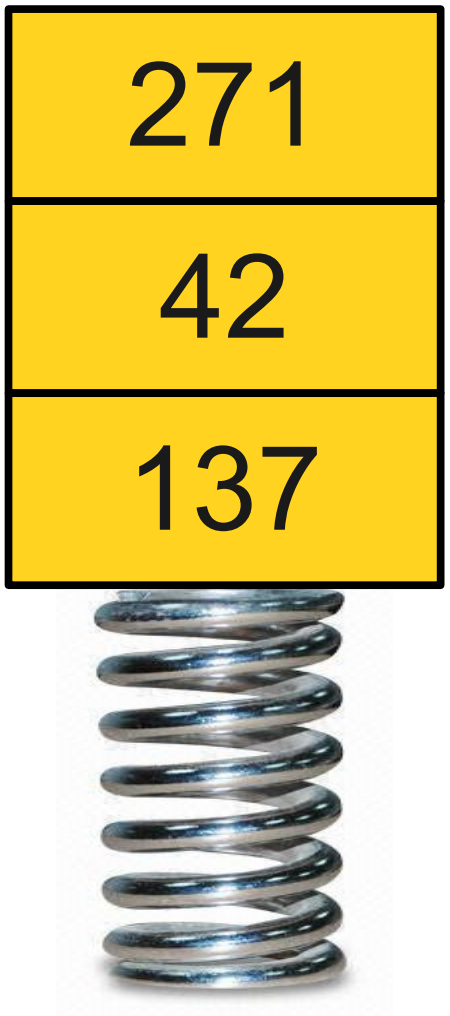
- A **`Stack`** is a data structure representing a stack of things.
- Objects can be **pushed** on top of the stack or **popped** from the top of the stack.
- No other objects in the stack are visible.
- Example: Function calls

Stack

- A **`Stack`** is a data structure representing a stack of things.
- Objects can be **pushed** on top of the stack or **popped** from the top of the stack.
- No other objects in the stack are visible.
- Example: Function calls

Stack

- A **`Stack`** is a data structure representing a stack of things.
- Objects can be **pushed** on top of the stack or **popped** from the top of the stack.
- No other objects in the stack are visible.
- Example: Function calls

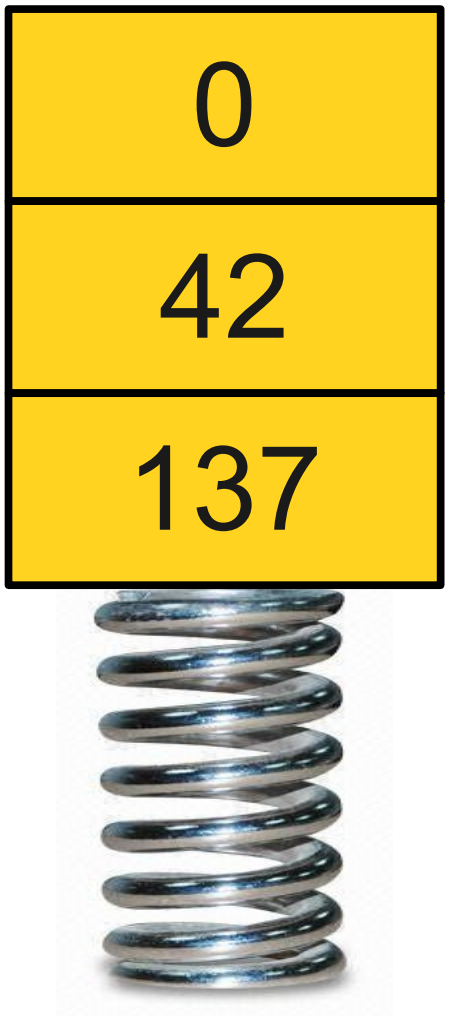


Stack

- A **`Stack`** is a data structure representing a stack of things.
- Objects can be **pushed** on top of the stack or **popped** from the top of the stack.
- No other objects in the stack are visible.
- Example: Function calls

Stack

- A **`Stack`** is a data structure representing a stack of things.
- Objects can be **pushed** on top of the stack or **popped** from the top of the stack.
- No other objects in the stack are visible.
- Example: Function calls



Wait a Minute...

- But couldn't we just use a `Vector` for this?
- To push, just append:

v += ***elem***

- To pop, remove the last element:

```
v.removeAt(v.length() - 1);
```

Stacks Matter

- There are several major advantages to using a stack.
- **Conceptual simplicity**:
  - Describing a problem as a stack rather than a vector more precisely describes the problem.
  - Recognizing this use pattern sheds light on the structure of multiple related problems.
- **Implementation efficiency**:
  - Stacks can be implemented slightly more efficiently than vectors; more on that later.

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
 ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
  ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
    ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
    ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
      ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
      ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
        ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
        ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
          ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
          ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
          ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
          ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
          ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
          ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
            ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
            ^
```

Balancing Parentheses

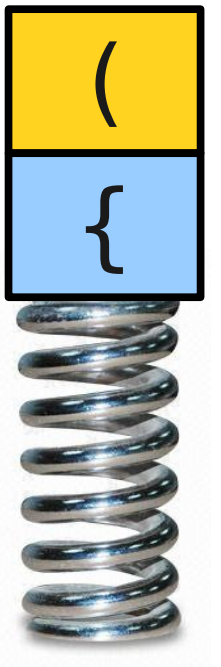
```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
            ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
          ^
```

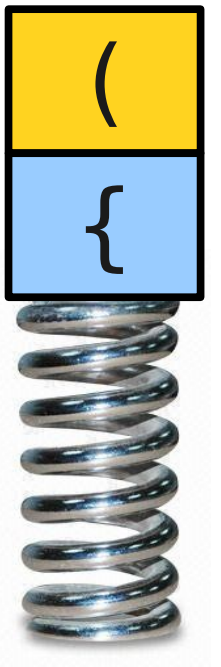
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
          ^
```



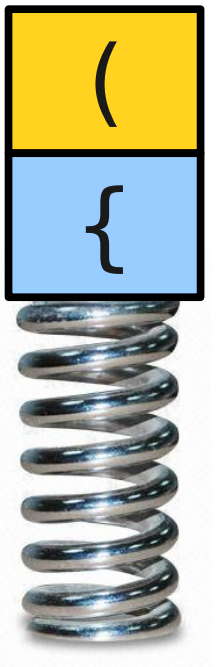
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                ^
```



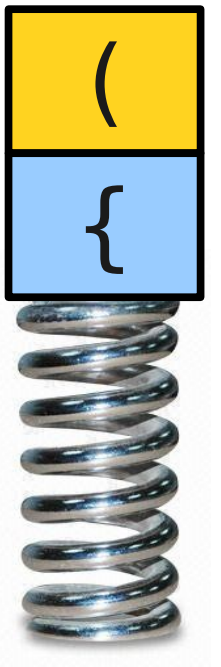
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                ^
```



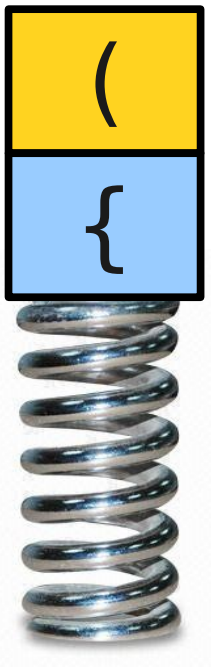
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                  ^
```



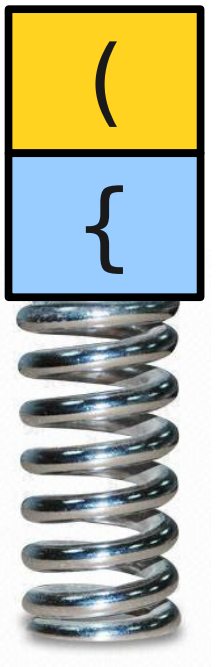
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                  ^
```



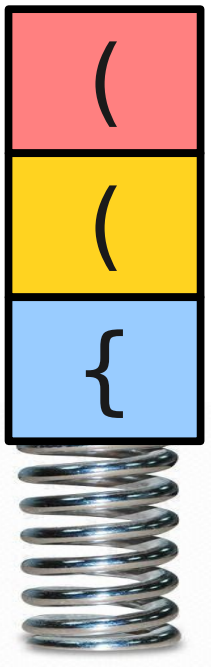
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                    ^
```



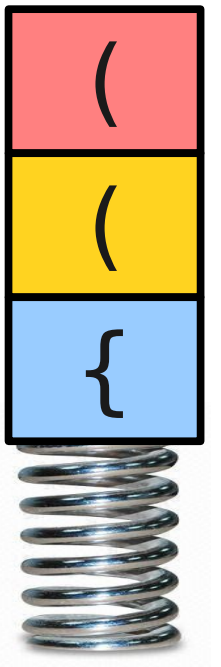
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                    ^
```



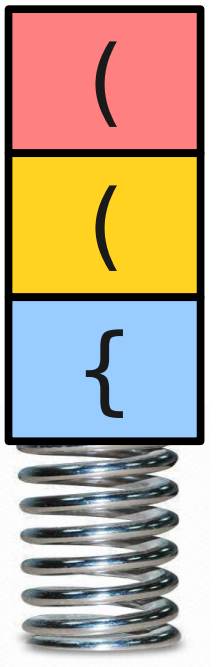
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                    ^
```



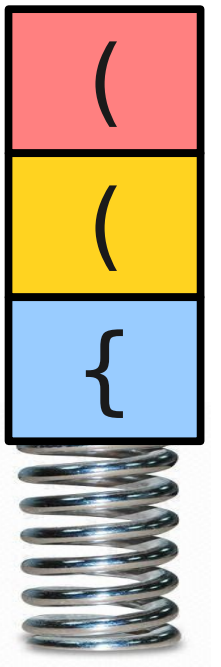
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                    ^
```



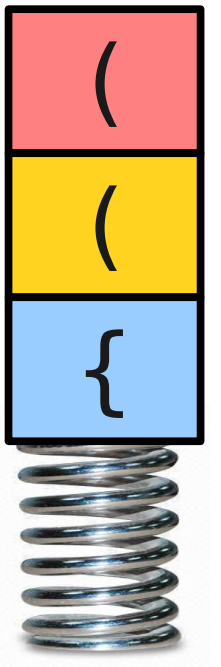
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                        ^
```



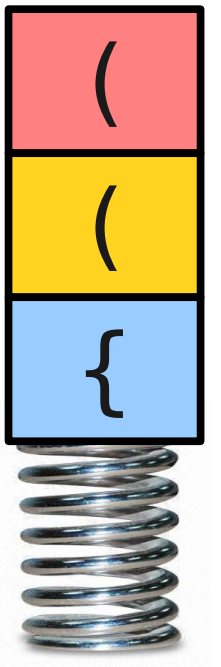
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                          ^
```



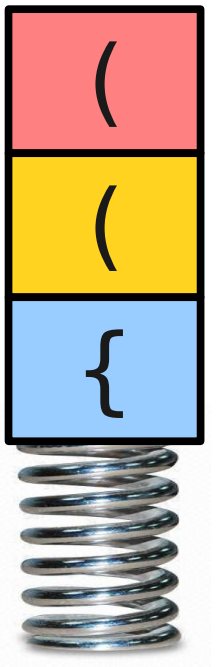
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                          ^
```



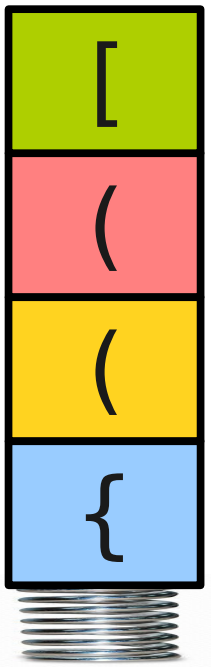
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                          ^
```



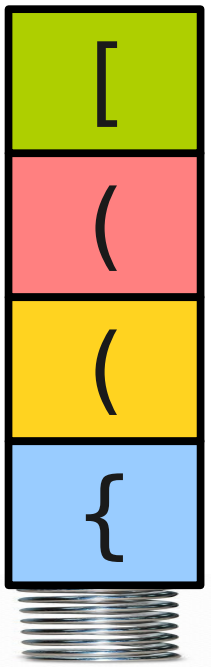
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                          ^
```



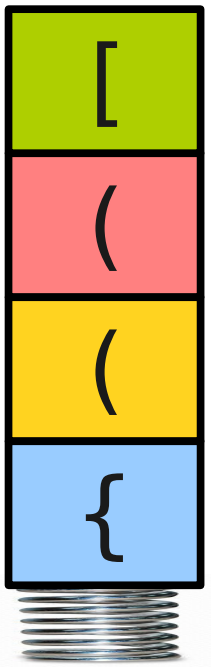
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                          ^
```



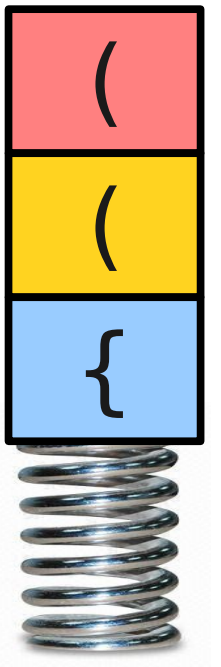
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                          ^
```



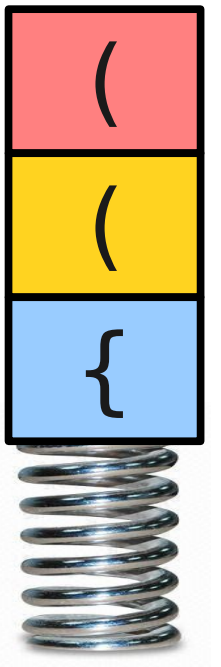
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                          ^
```



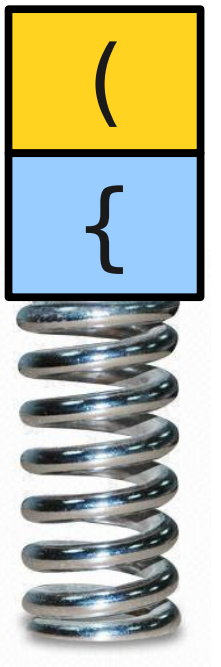
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                              ^
```



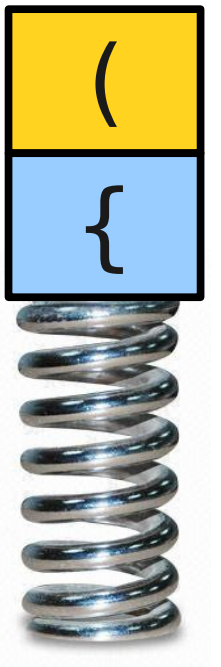
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                ^
```



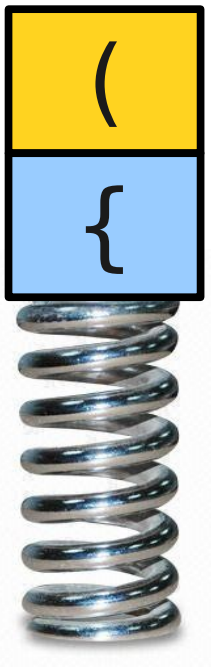
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                ^
```



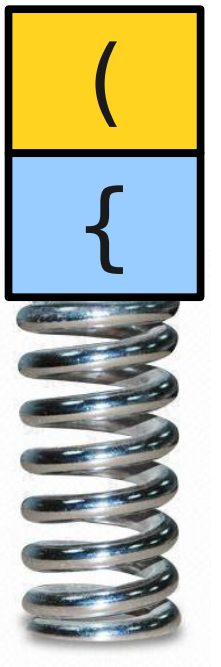
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                ^
```



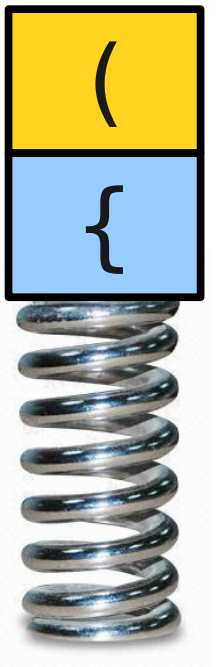
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                 ^
```



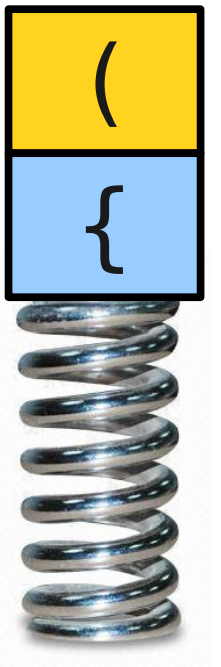
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                  ^
```



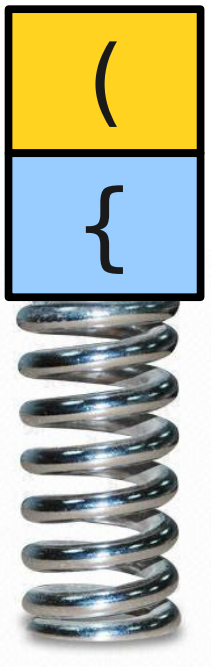
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                  ^
```



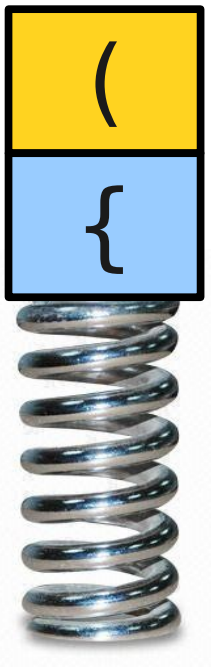
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                  ^
```



Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                  ^
```



Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                  ^
```

Balancing Parentheses

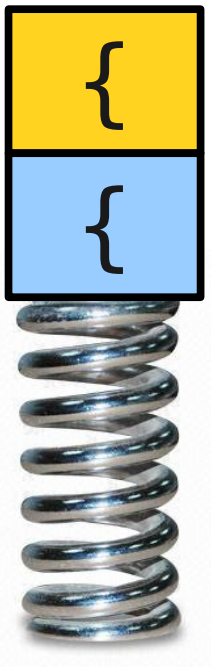
```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                      ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                      ^
```

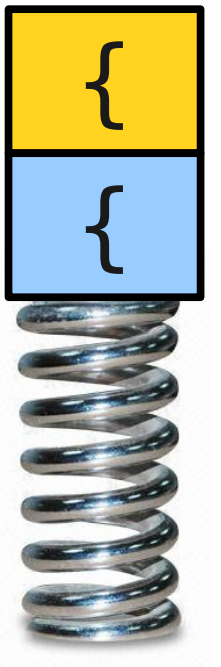
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                      ^
```



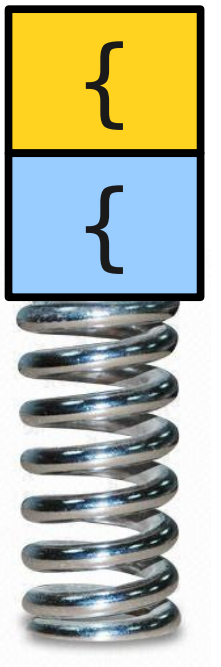
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                      ^
```



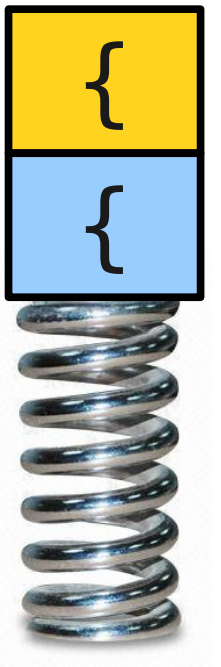
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                        ^
```



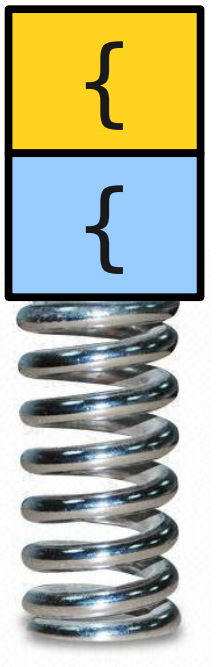
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                      ^
```



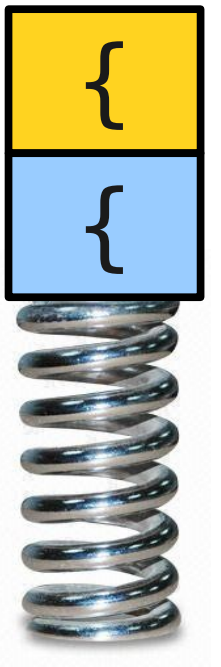
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                        ^
```



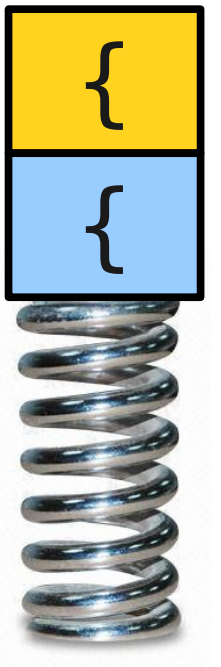
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                          ^
```



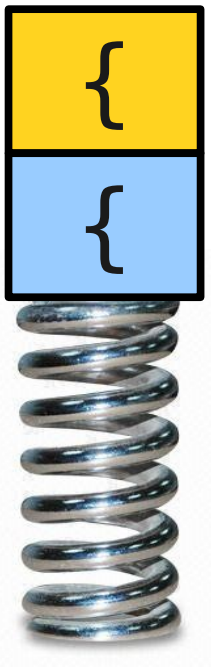
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                          ^
```



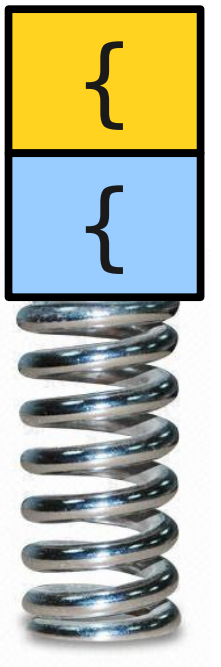
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                          ^
```



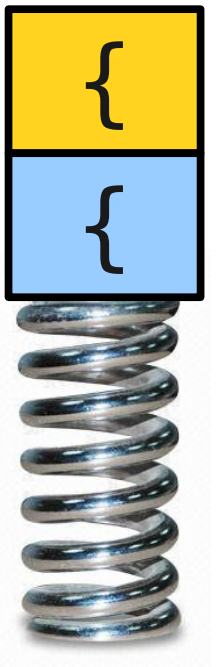
Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                              ^
```



Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                              ^
```



Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                              ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                                ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                                ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                                ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
                                                 ^
```

Balancing Parentheses

```
int foo() { if (x * (y + z[1]) < 137) { x = 1; } }
```

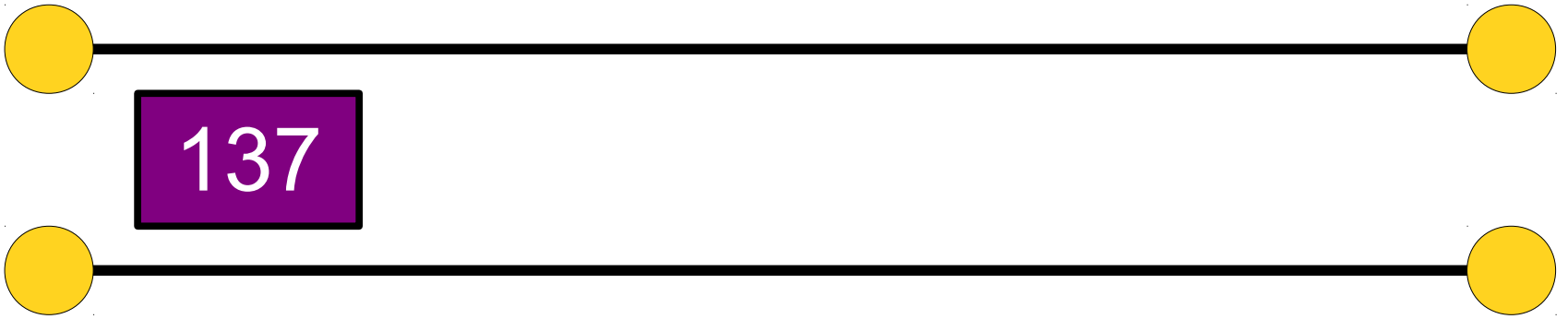
Queue

Queue

- A **Queue** is a data structure representing a waiting line.
- Objects can be **enqueued** to the back of the line or **dequeued** from the front of the line.
- No other objects in the queue are visible.
- Example: A checkout counter.

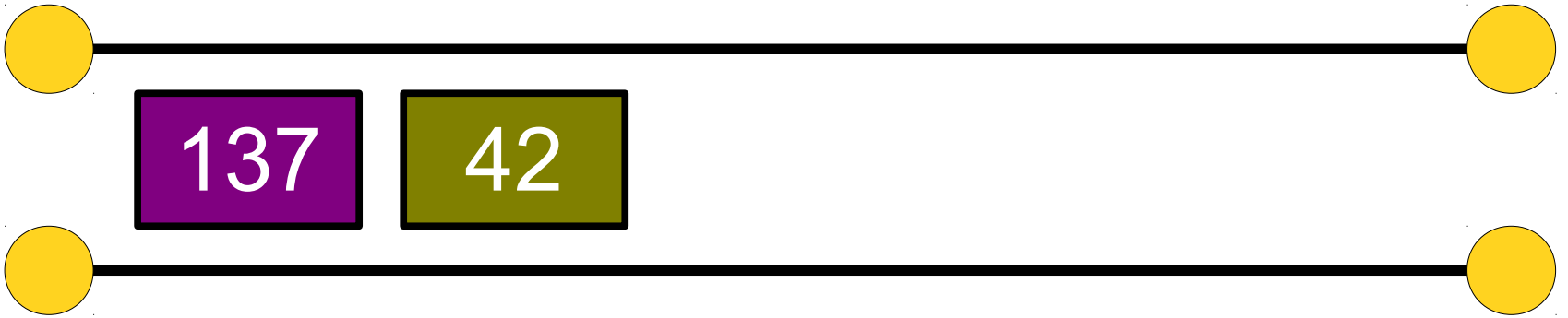
Queue

- A **Queue** is a data structure representing a waiting line.
- Objects can be **enqueued** to the back of the line or **dequeued** from the front of the line.
- No other objects in the queue are visible.
- Example: A checkout counter.



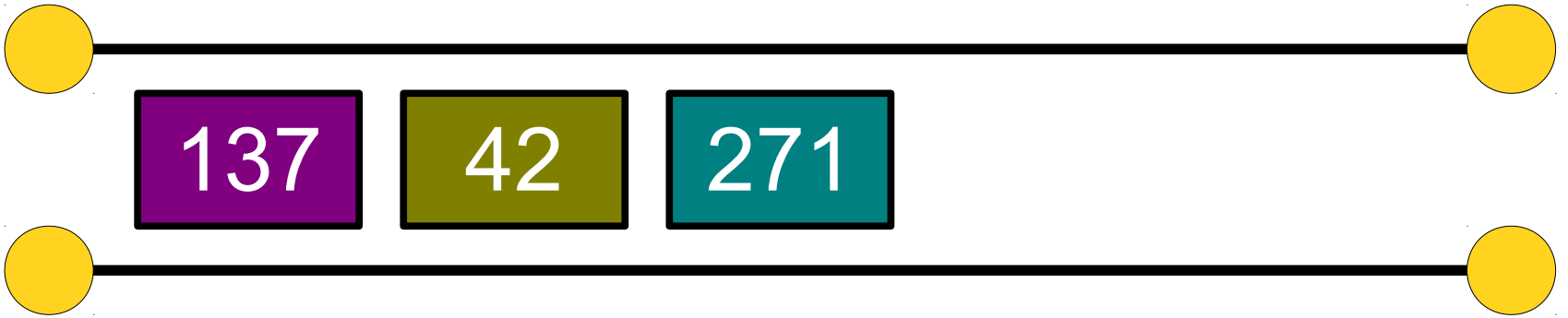
Queue

- A **Queue** is a data structure representing a waiting line.
- Objects can be **enqueued** to the back of the line or **dequeued** from the front of the line.
- No other objects in the queue are visible.
- Example: A checkout counter.



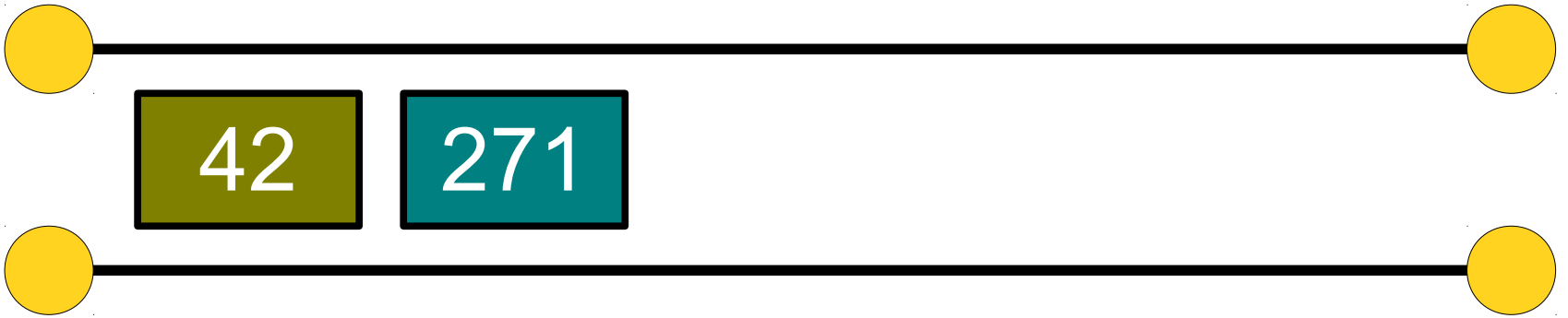
Queue

- A **Queue** is a data structure representing a waiting line.
- Objects can be **enqueued** to the back of the line or **dequeued** from the front of the line.
- No other objects in the queue are visible.
- Example: A checkout counter.



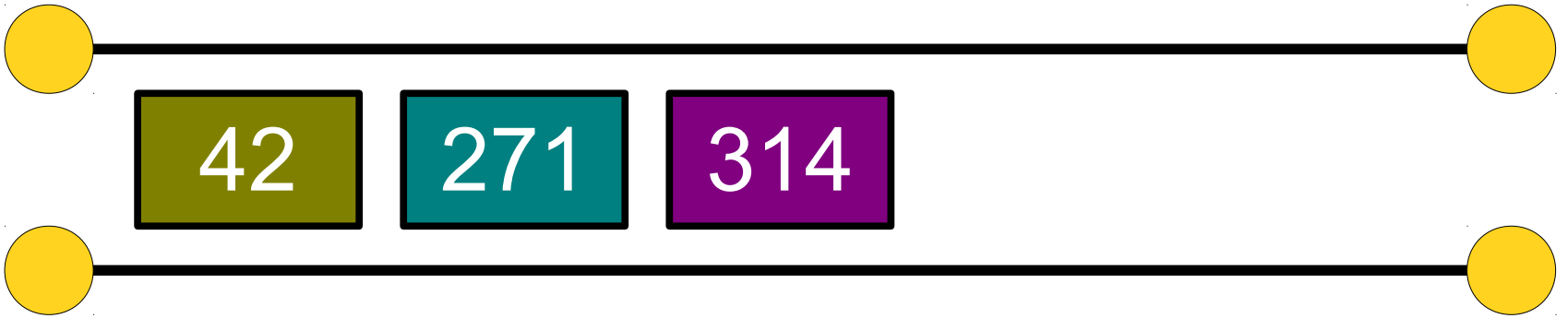
Queue

- A **Queue** is a data structure representing a waiting line.
- Objects can be **enqueued** to the back of the line or **dequeued** from the front of the line.
- No other objects in the queue are visible.
- Example: A checkout counter.



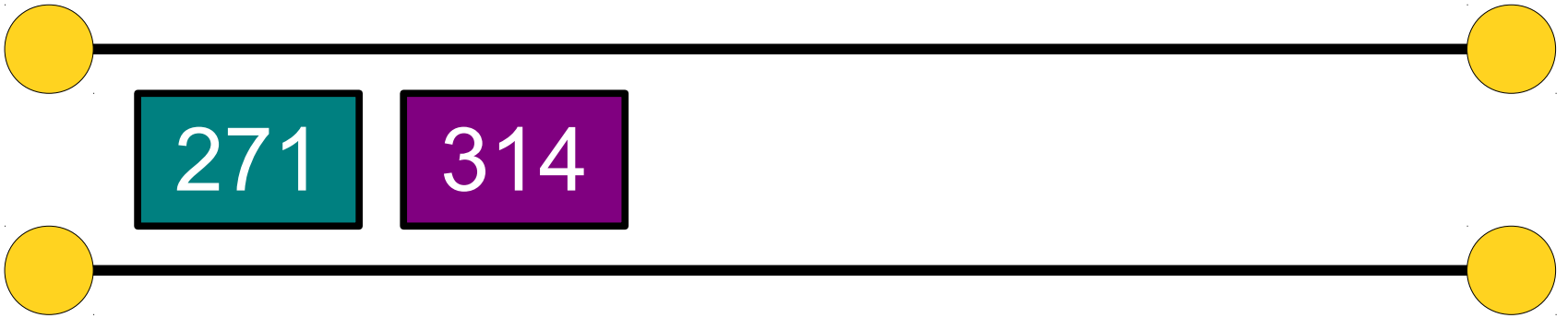
Queue

- A **Queue** is a data structure representing a waiting line.
- Objects can be **enqueued** to the back of the line or **dequeued** from the front of the line.
- No other objects in the queue are visible.
- Example: A checkout counter.



Queue

- A **Queue** is a data structure representing a waiting line.
- Objects can be **enqueued** to the back of the line or **dequeued** from the front of the line.
- No other objects in the queue are visible.
- Example: A checkout counter.



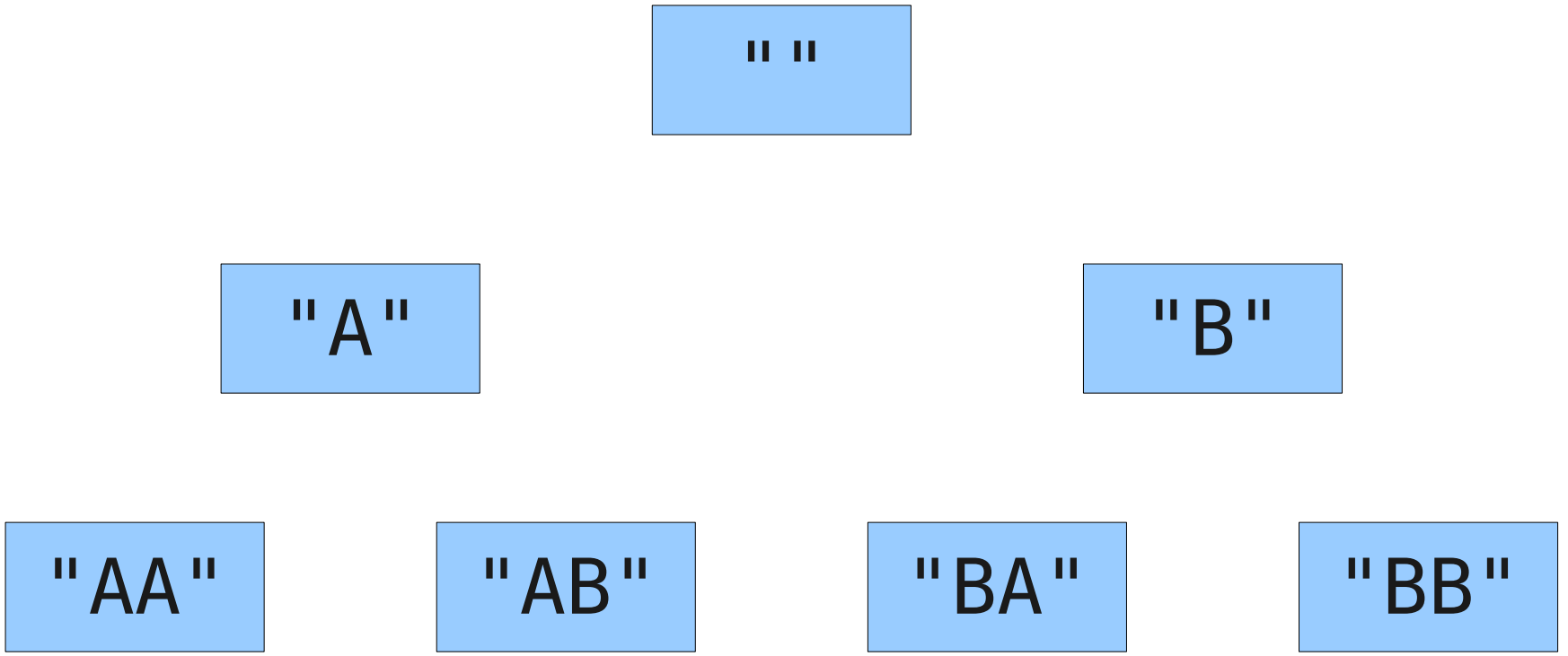
Queue

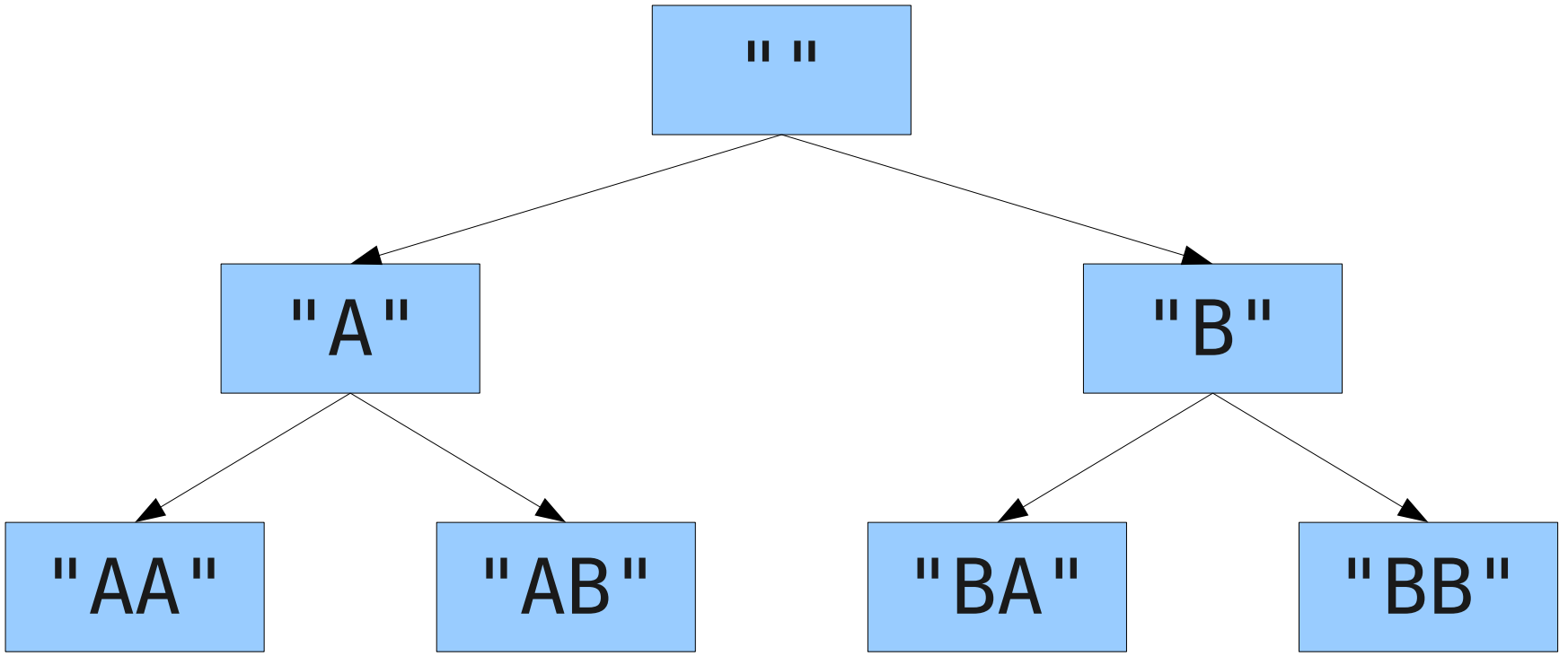
- A **Queue** is a data structure representing a waiting line.
- Objects can be **enqueued** to the back of the line or **dequeued** from the front of the line.
- No other objects in the queue are visible.
- Example: A checkout counter.

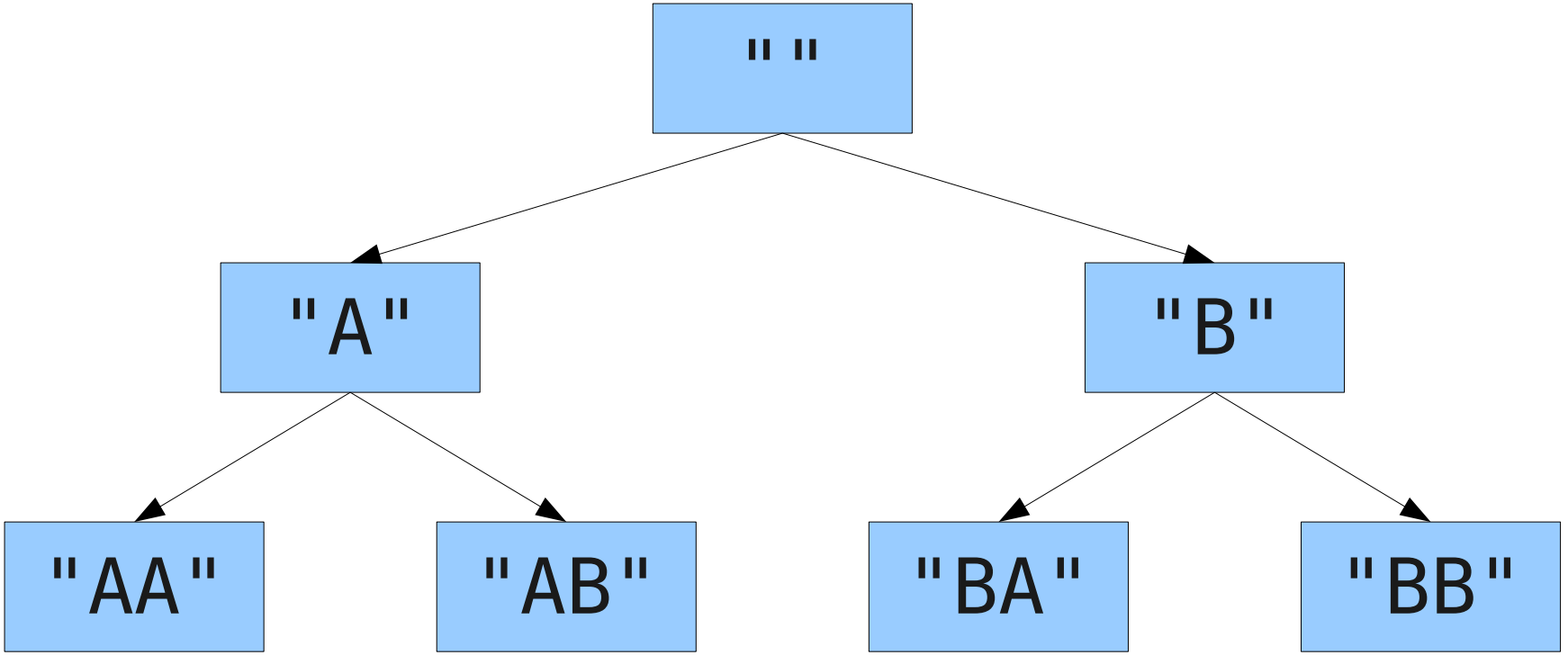
Listing All Strings

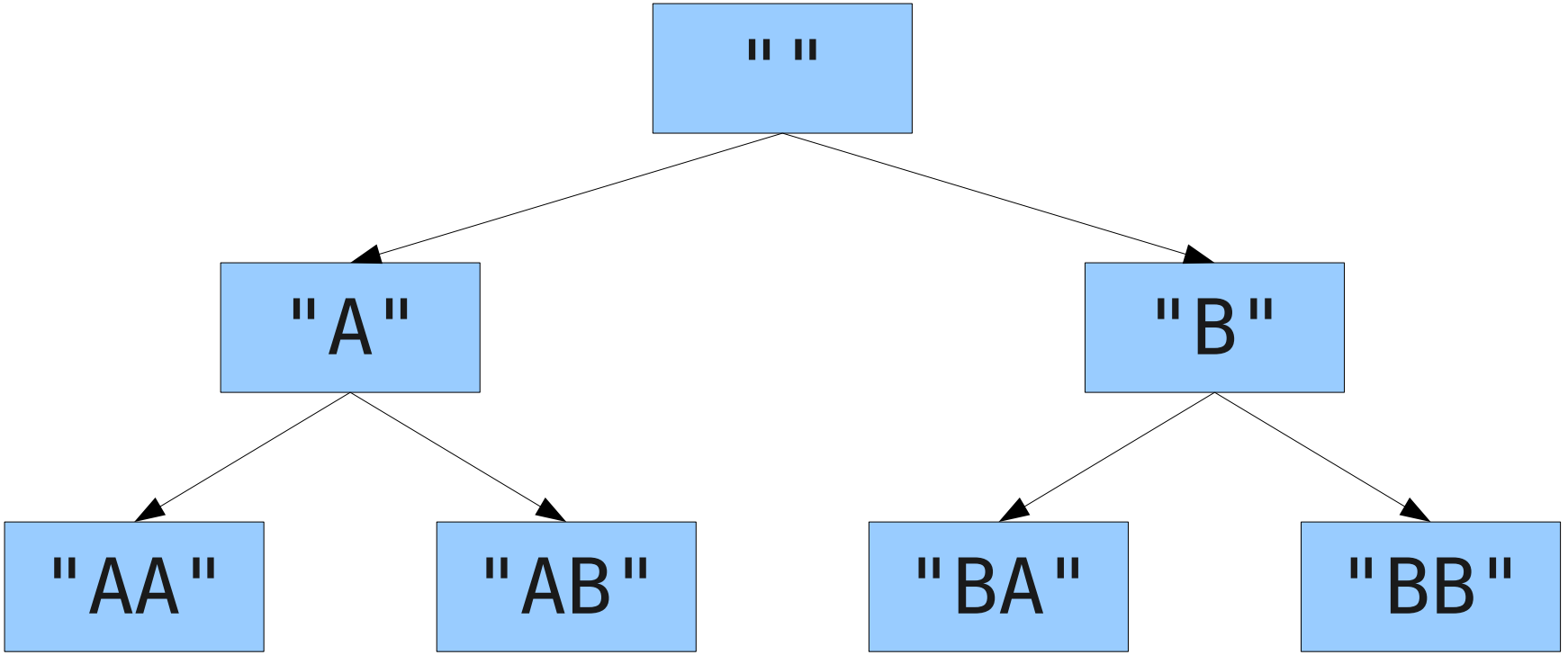
- Suppose we want to generate all strings of letters A, B, and C of length at most three.
- How might we do this?


" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

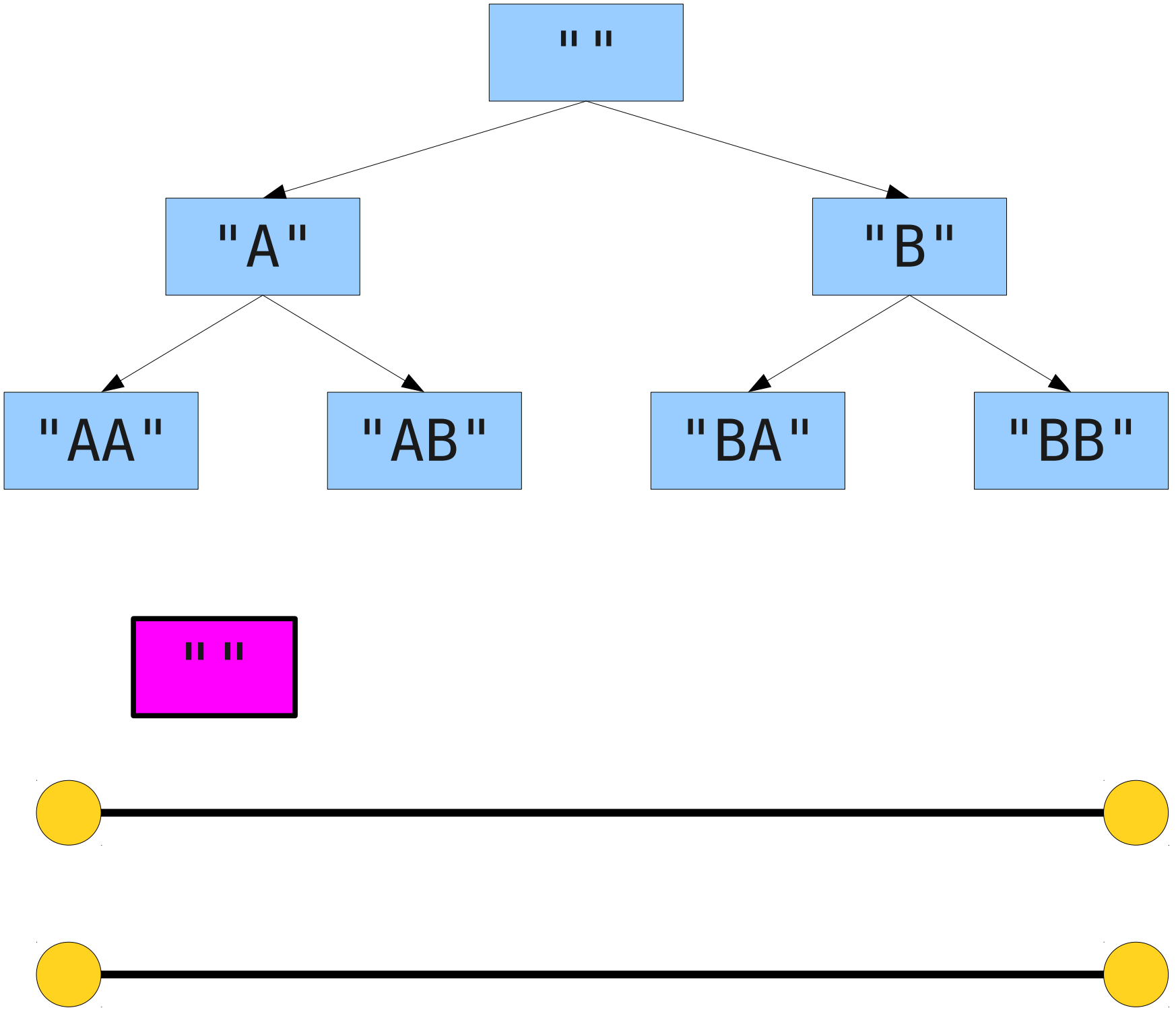

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

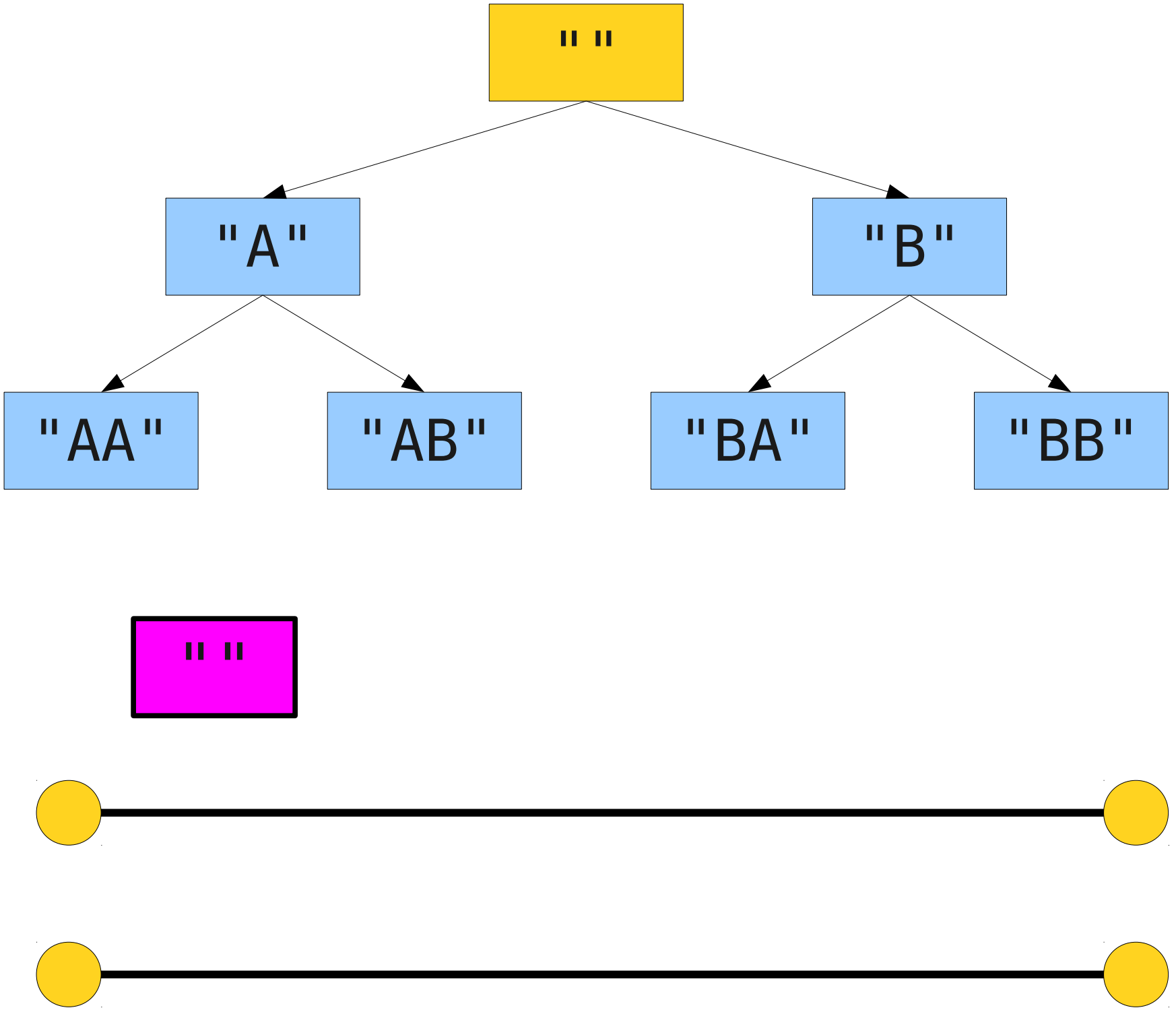

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

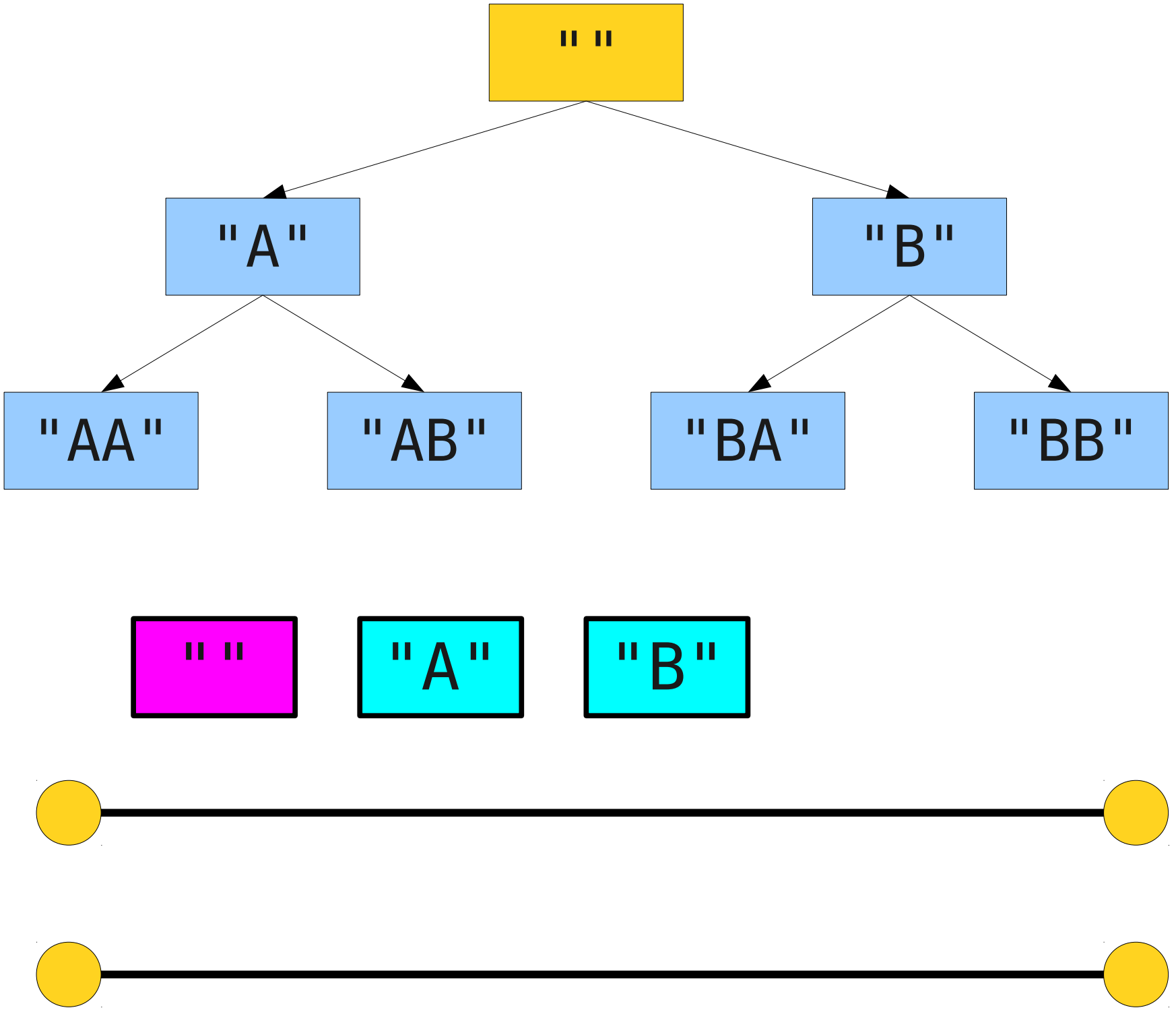

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

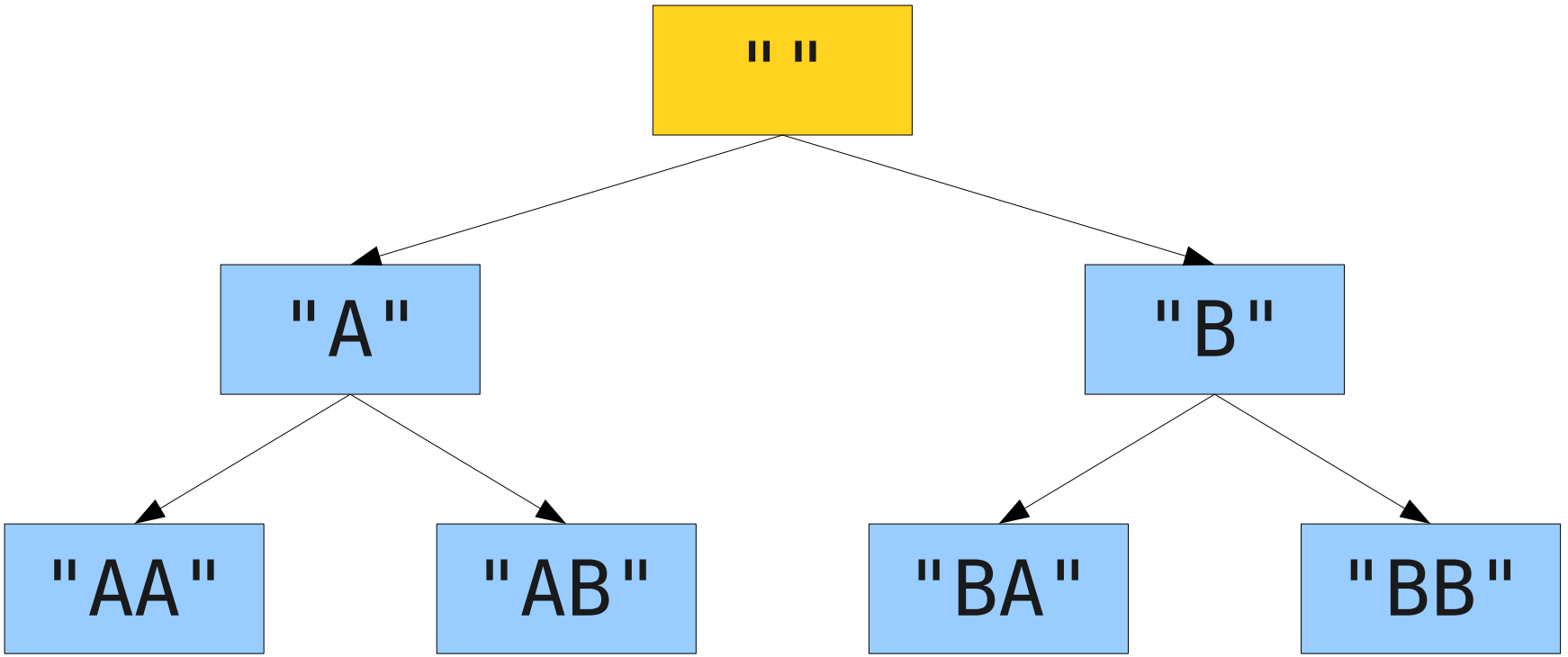

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

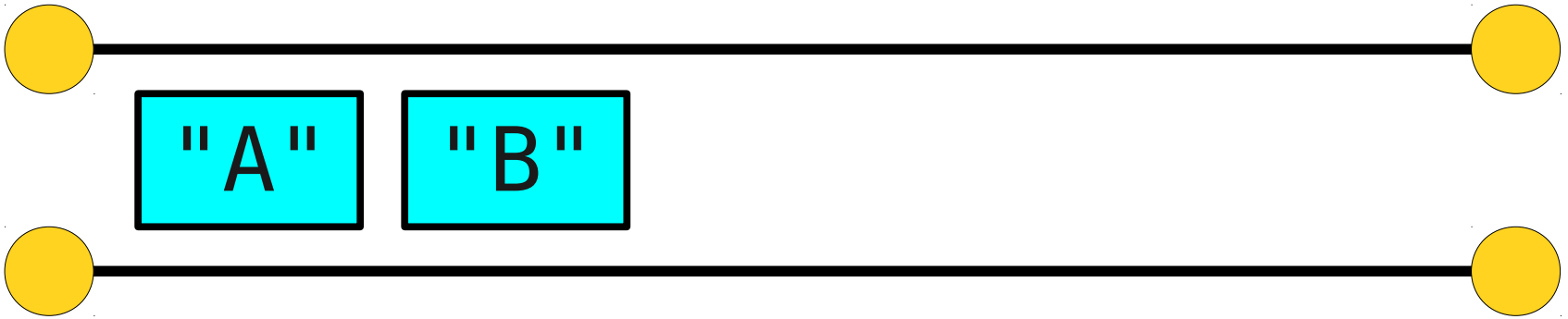

" "

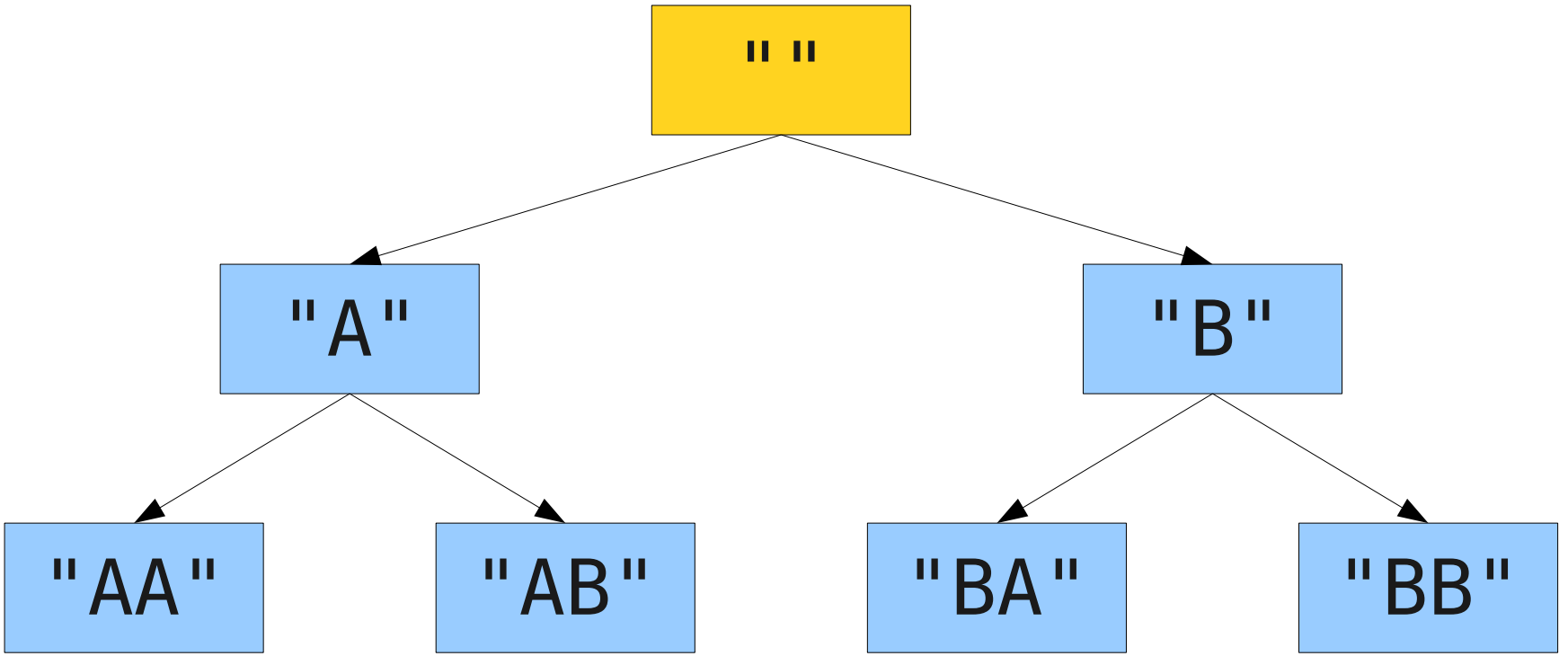

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"
" "

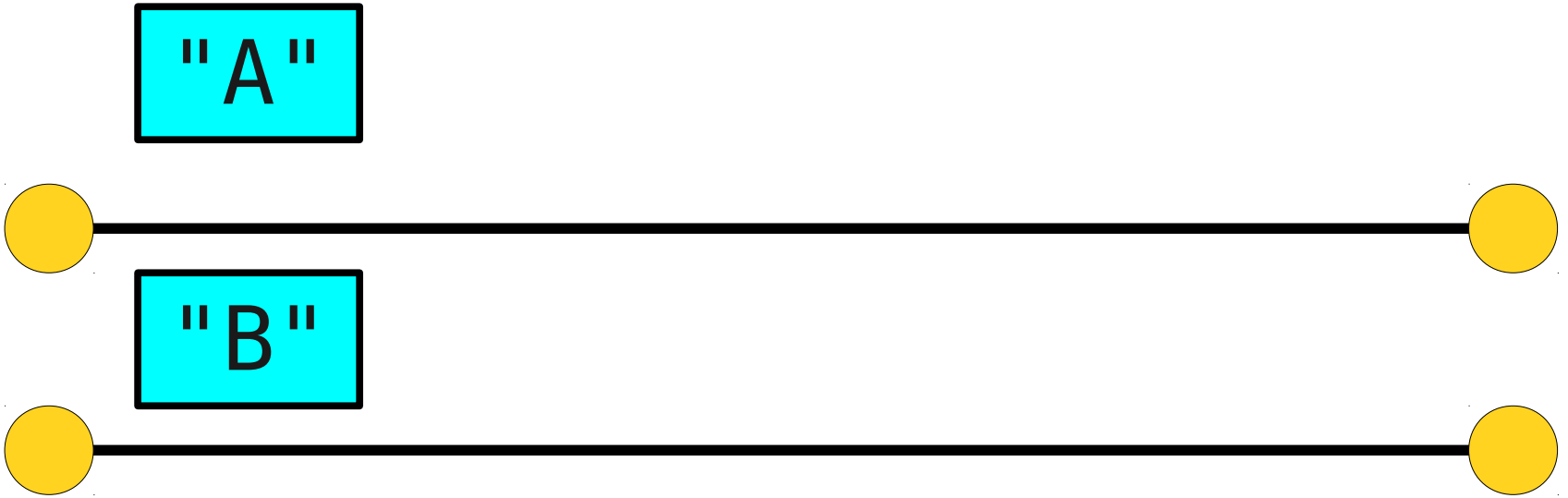

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"
" "

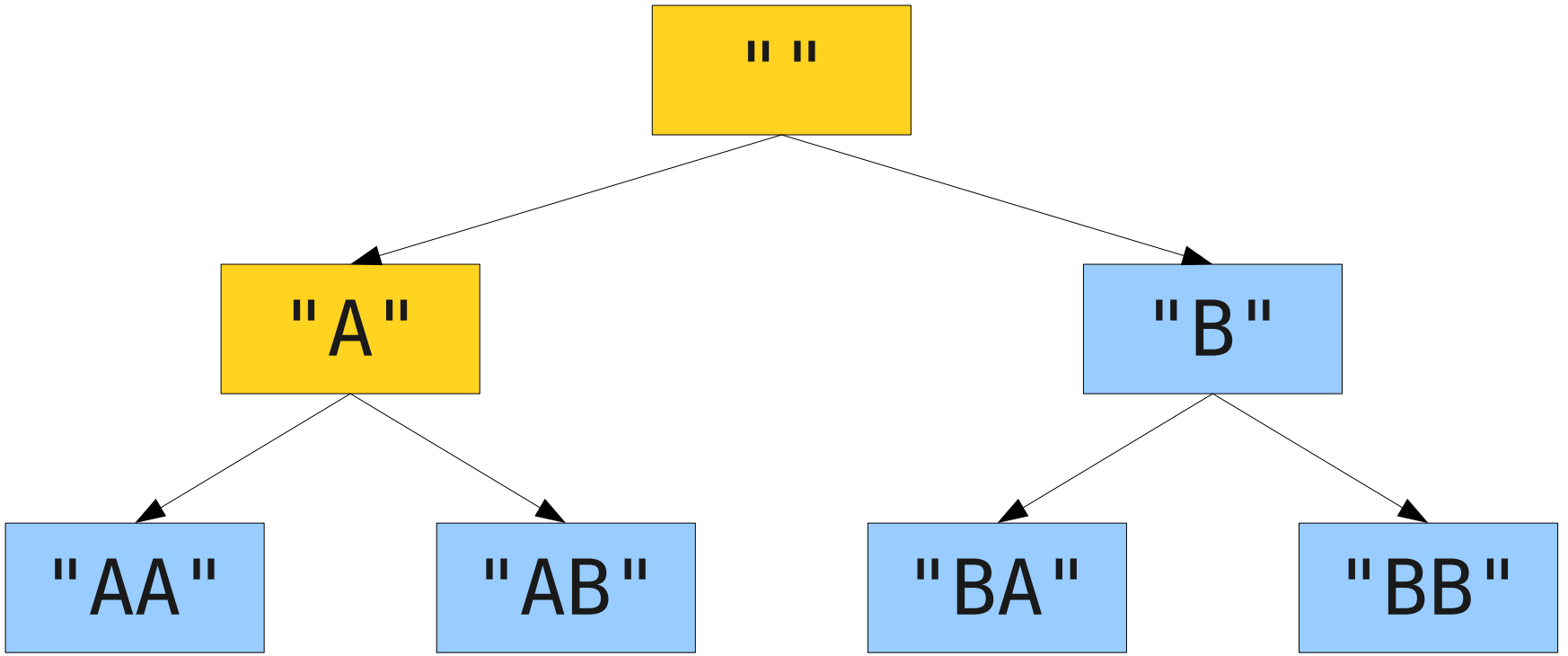

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"
" "
"A"
"B"

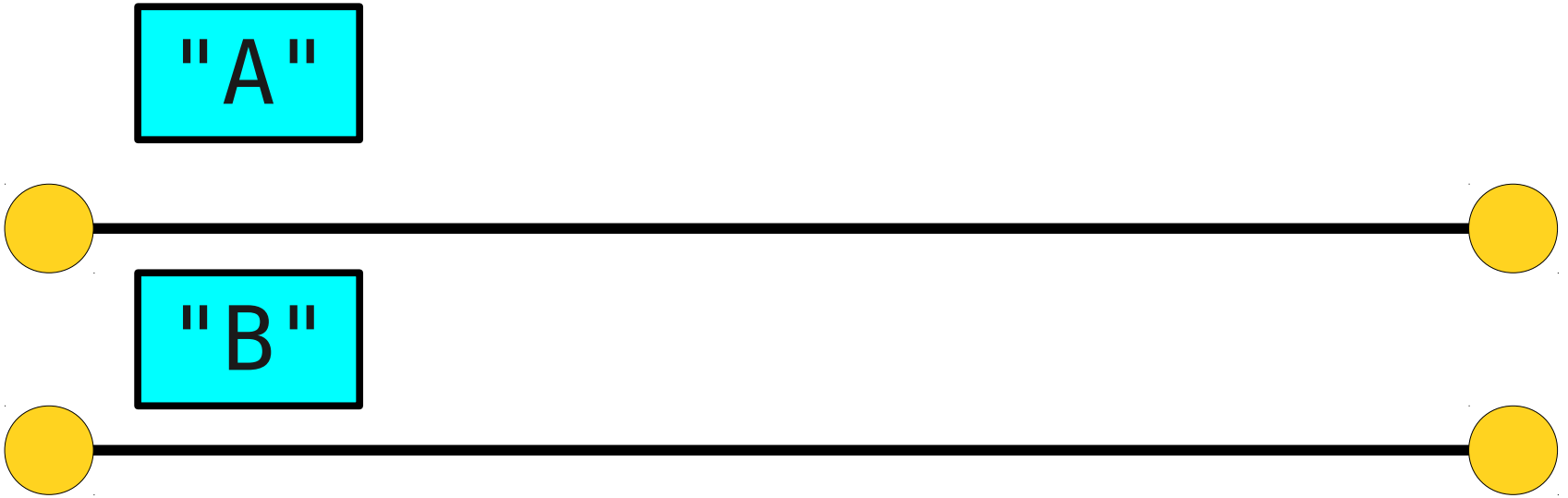

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

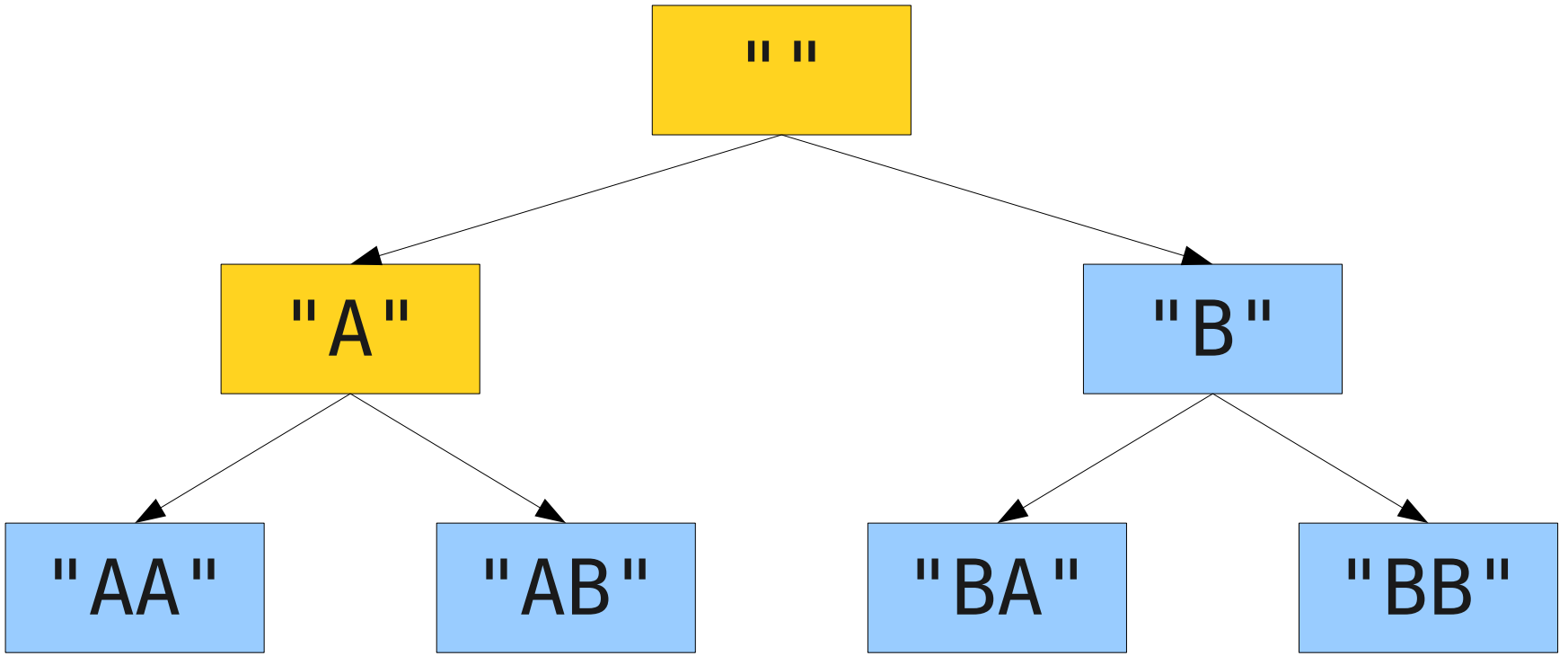

"A"
"B"

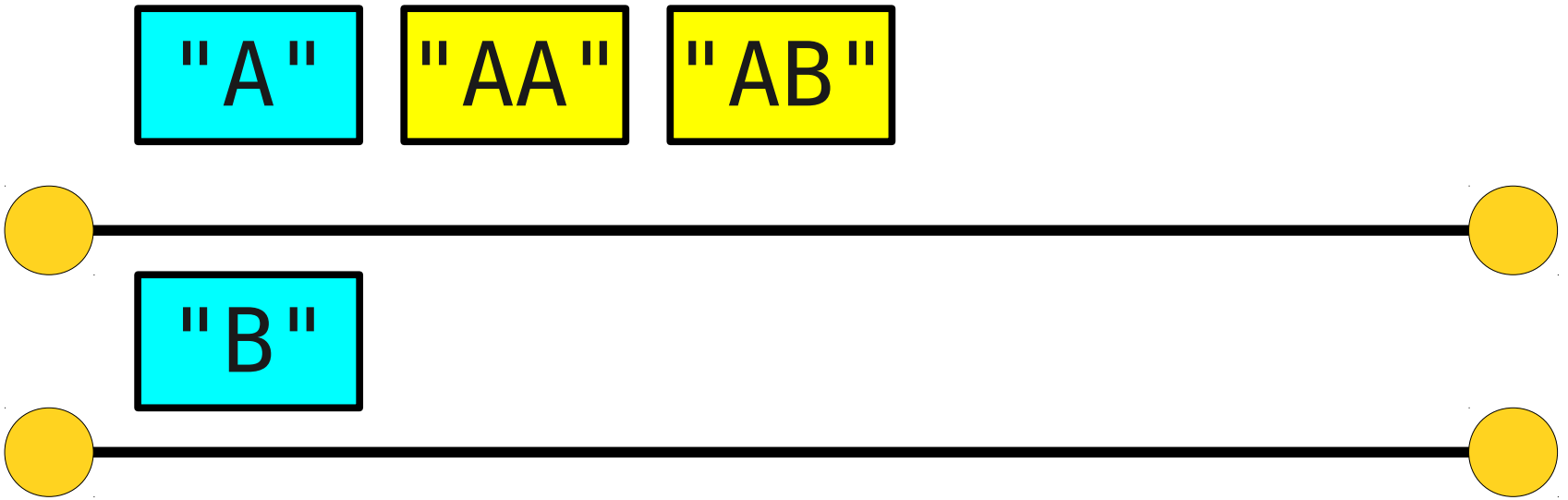

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

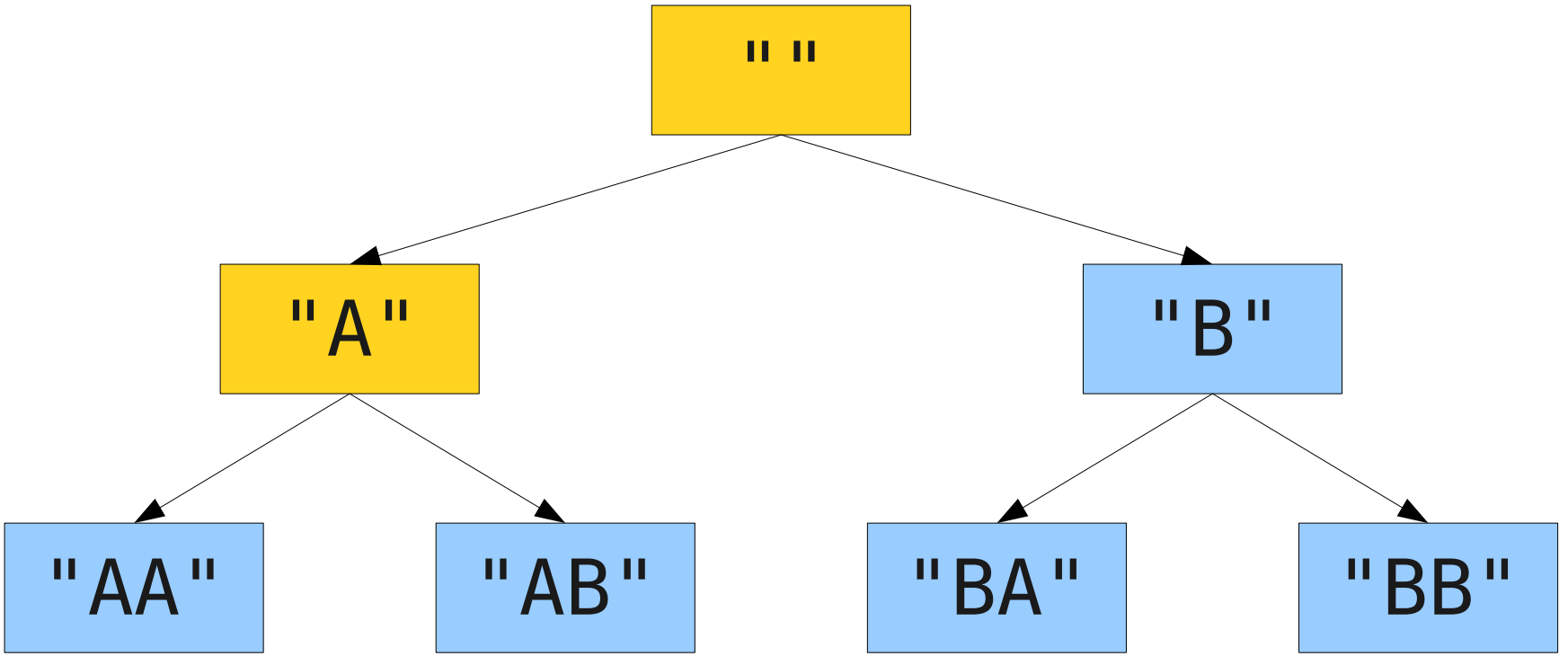

"A"
"B"

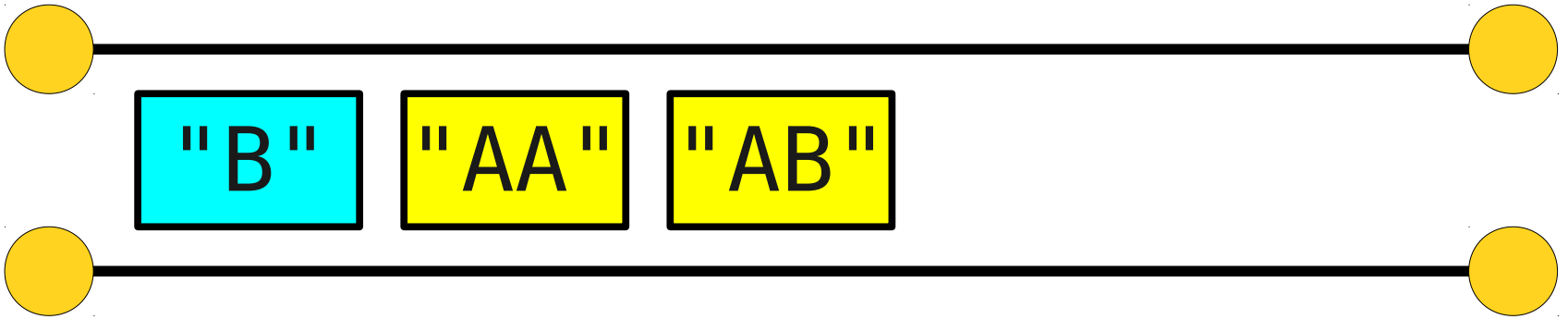

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

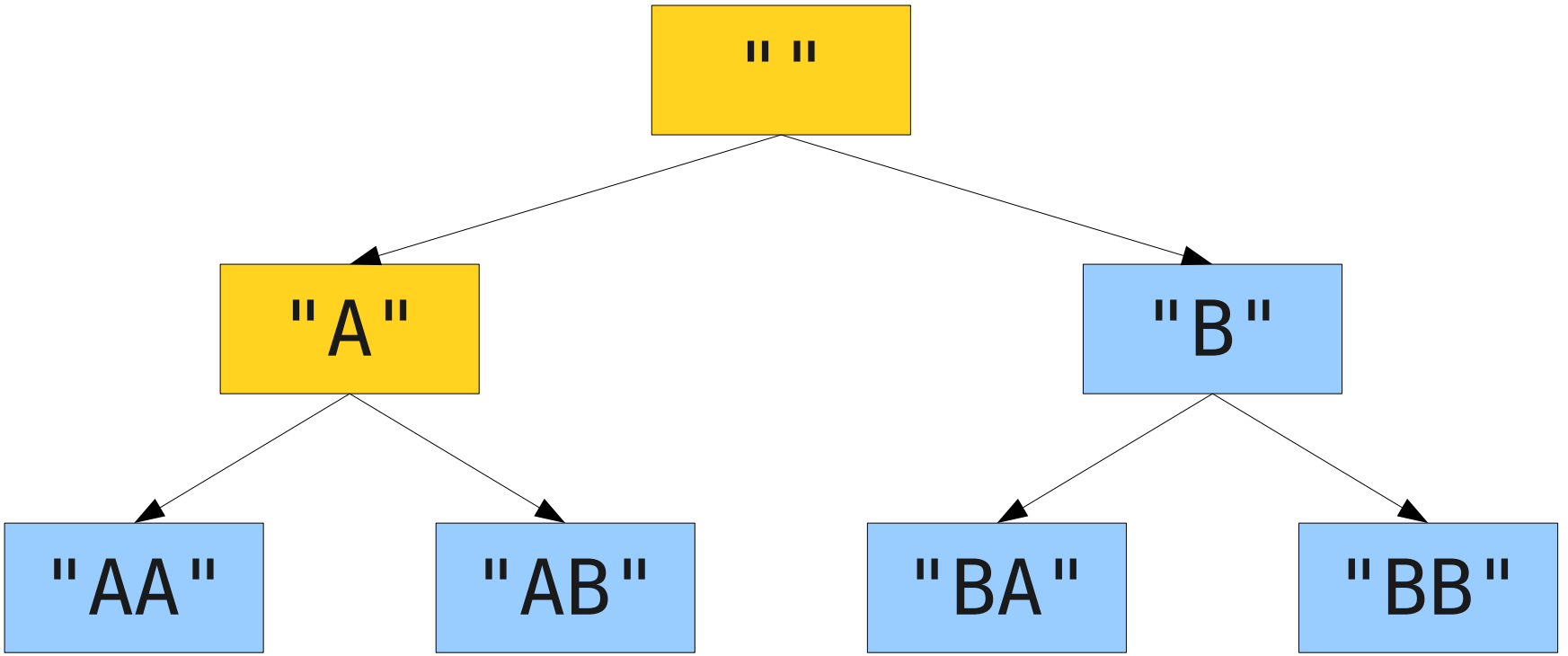

"A"
"B"

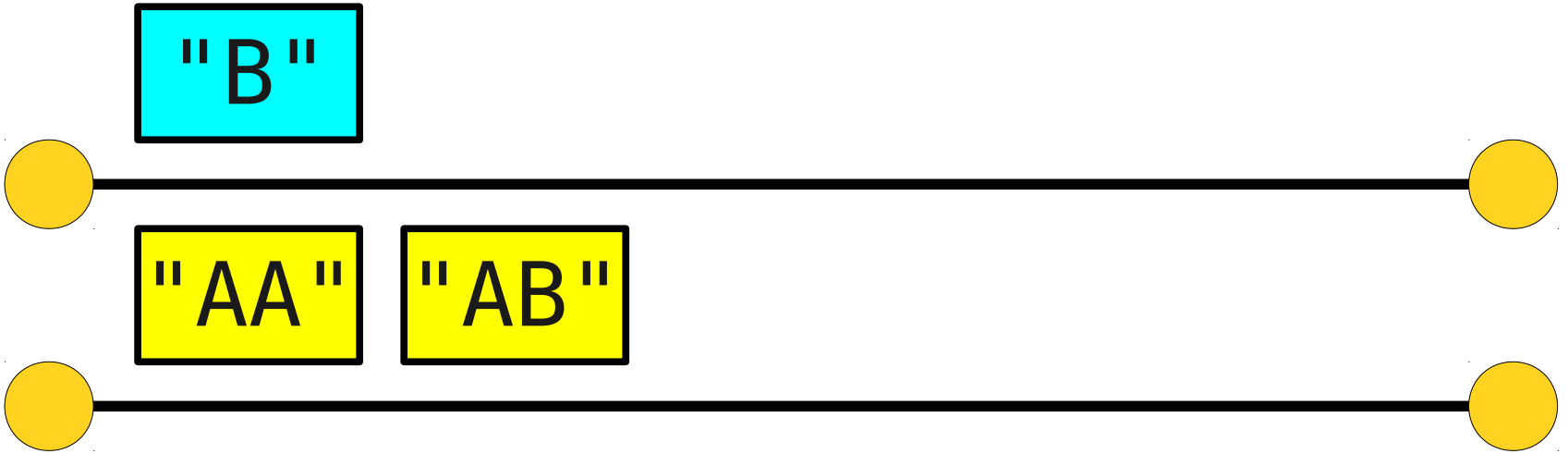

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

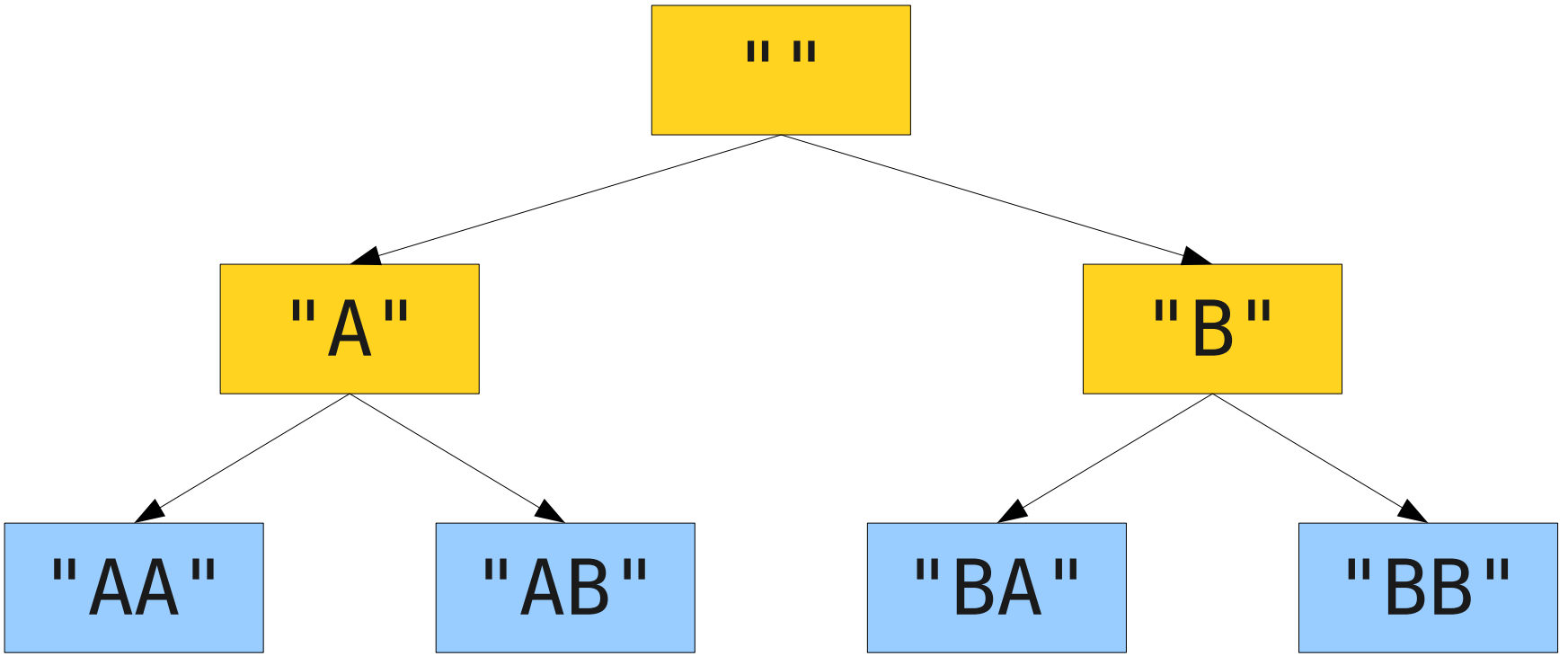

"A"
"AA"
"AB"
"B"

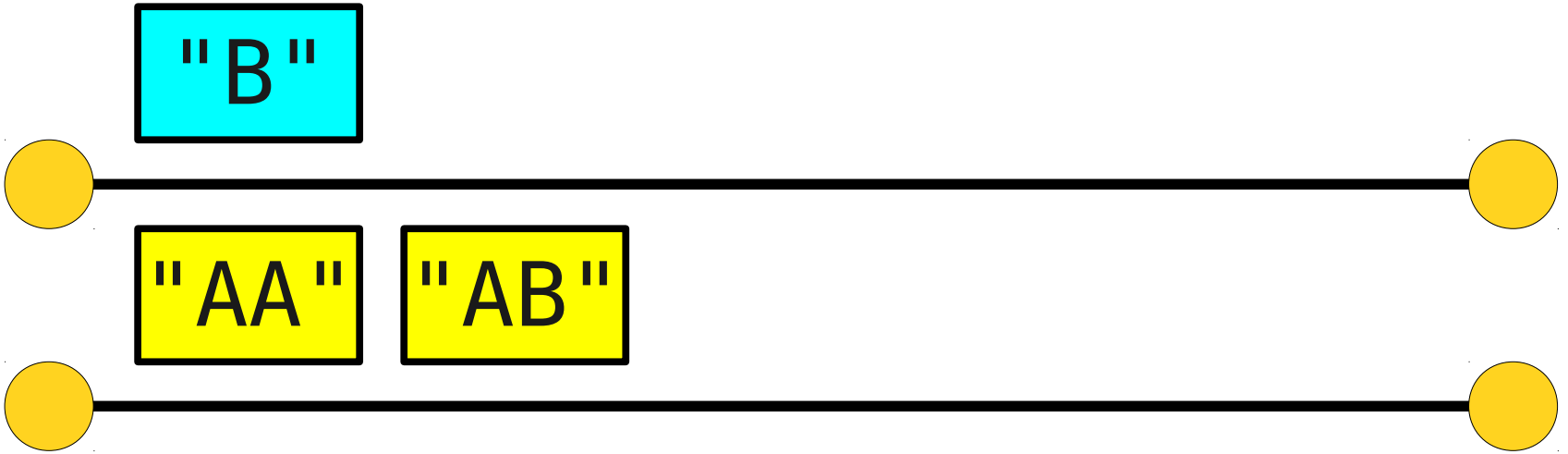

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

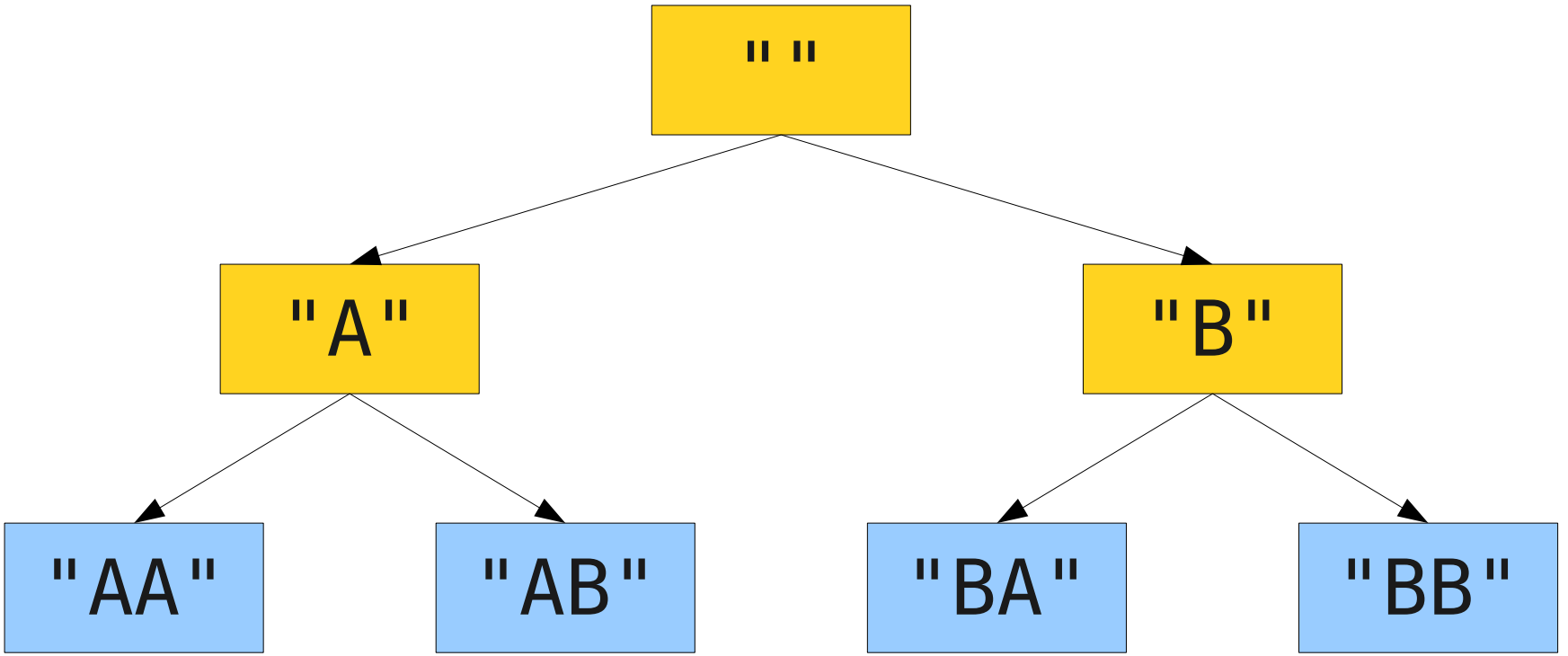

"B"
"AA"
"AB"

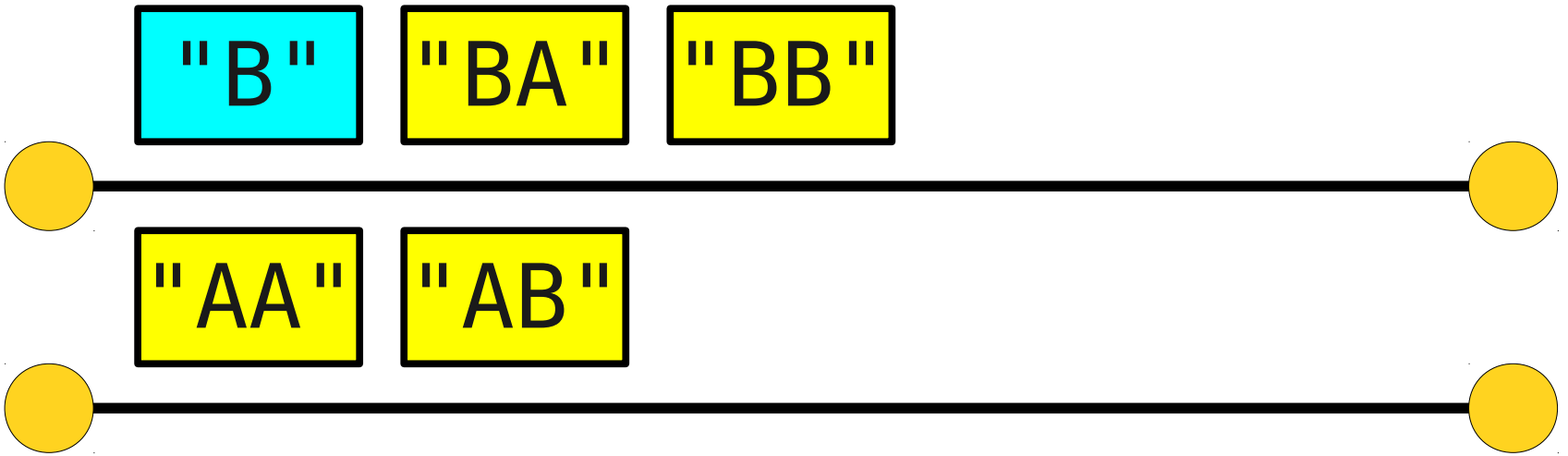

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

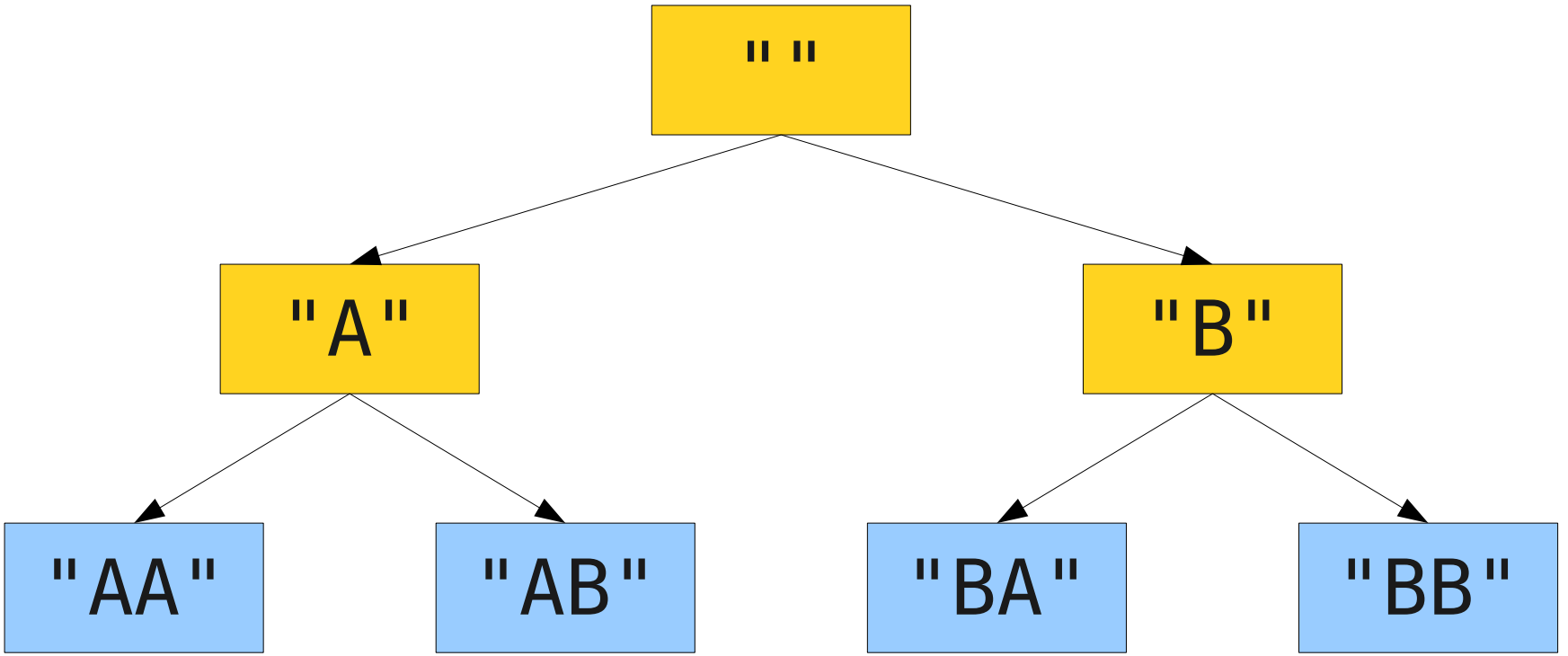

"B"
"AA"
"AB"

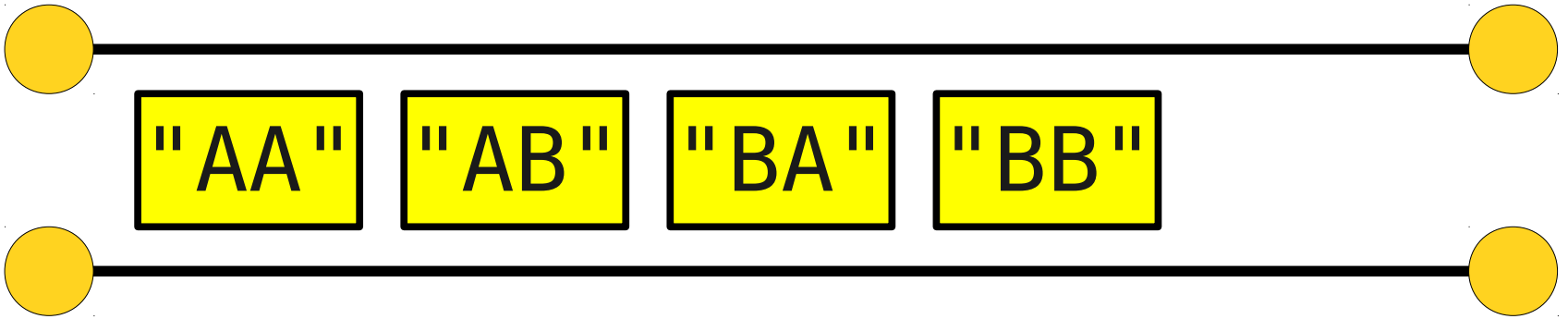

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

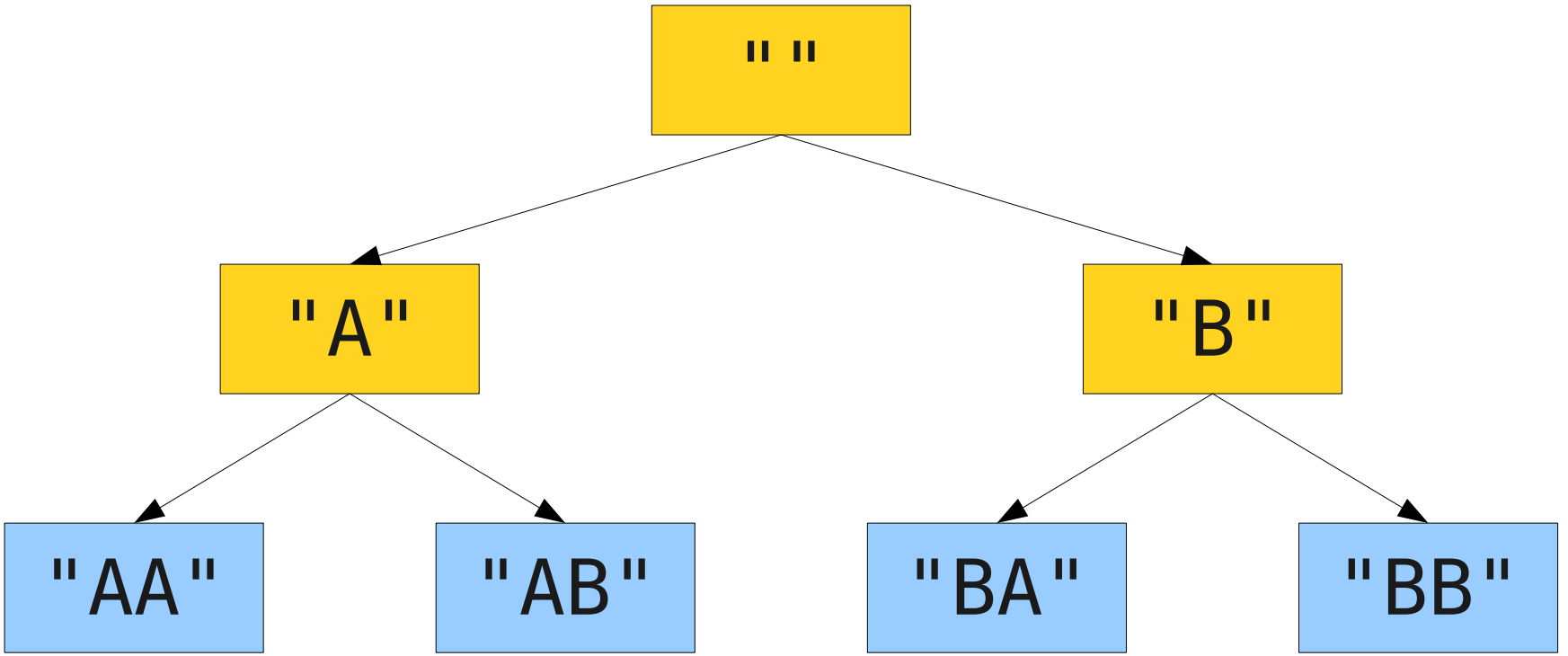

"B"
"AA"
"AB"

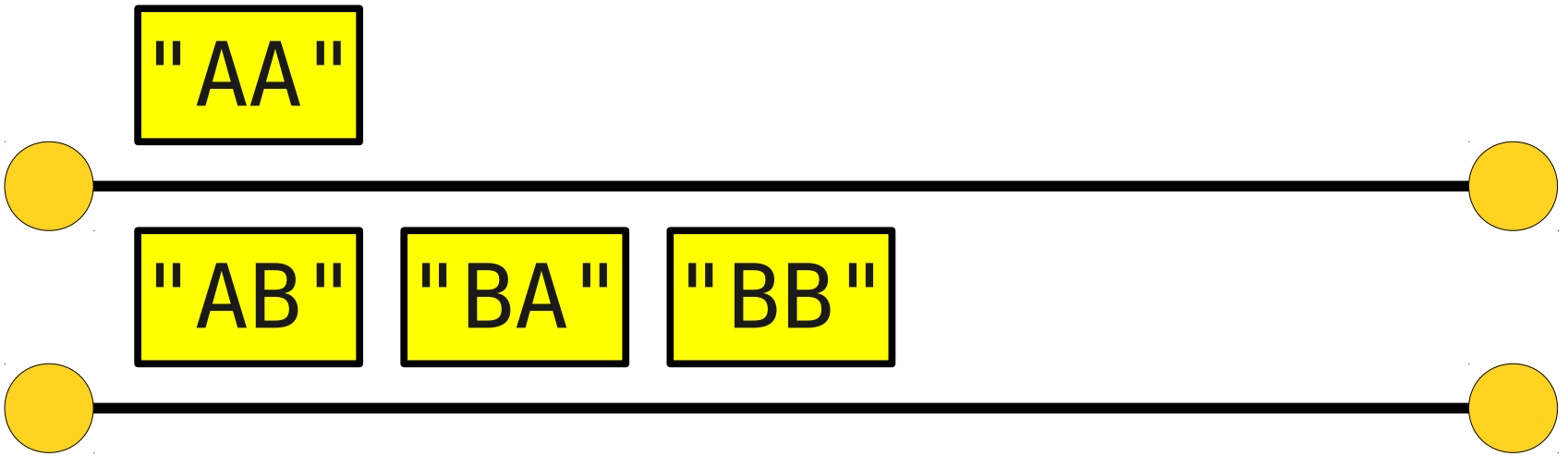

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

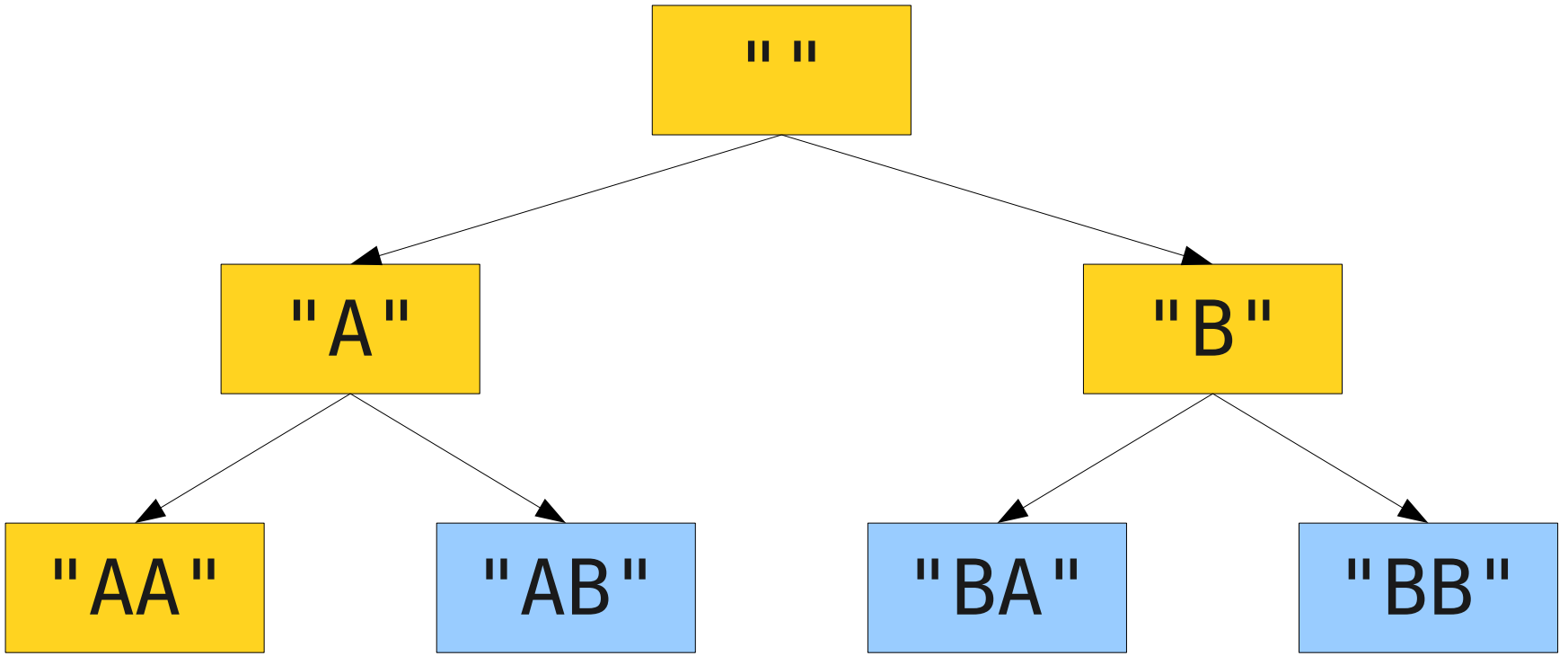

"B"
"BA"
"BB"
"AA"
"AB"

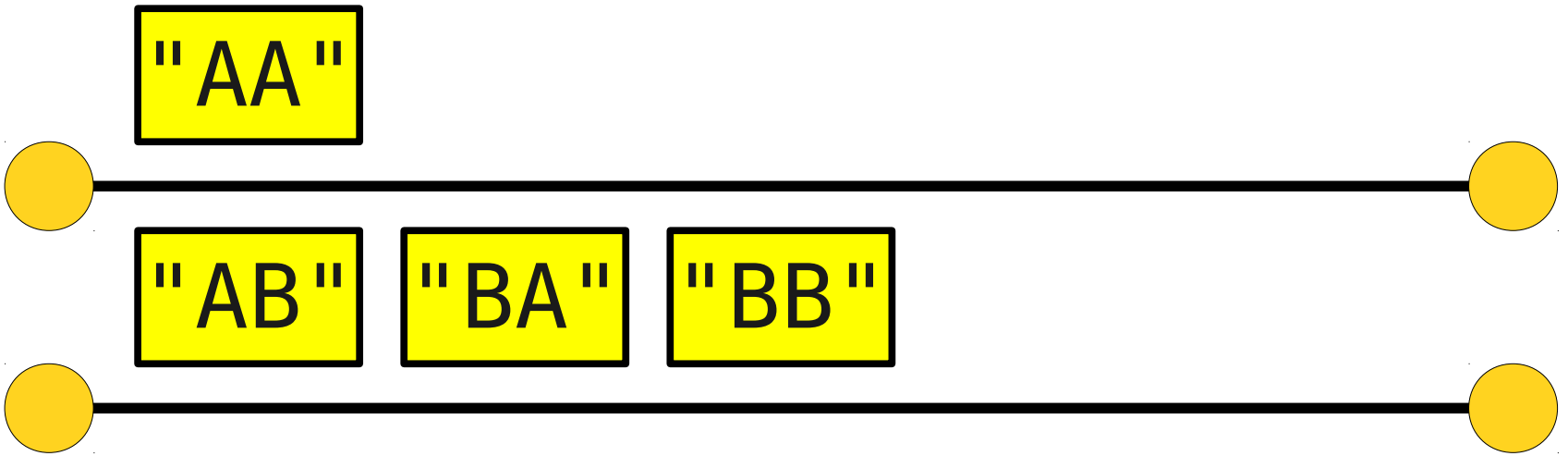

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

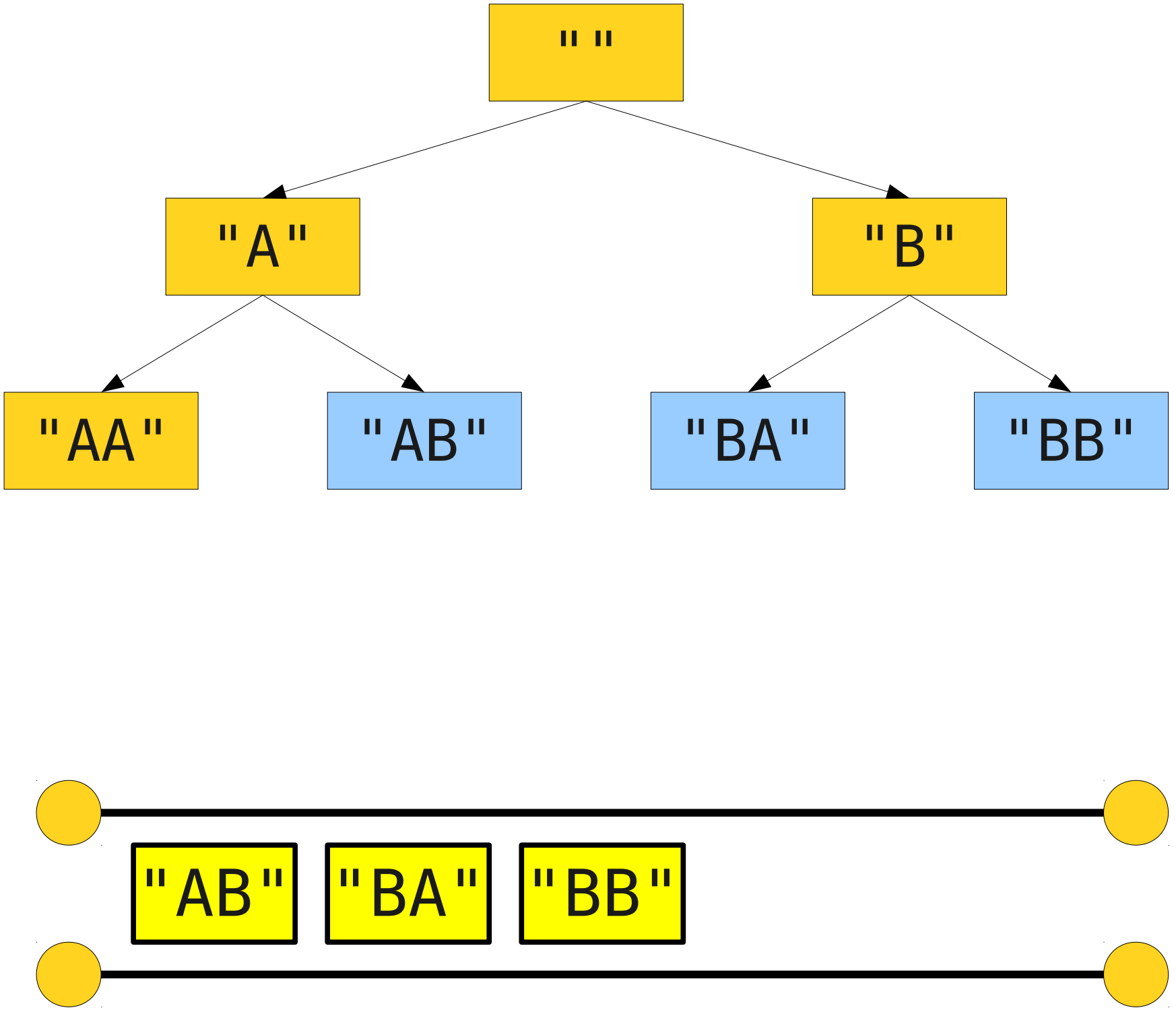

"AA"
"AB"
"BA"
"BB"

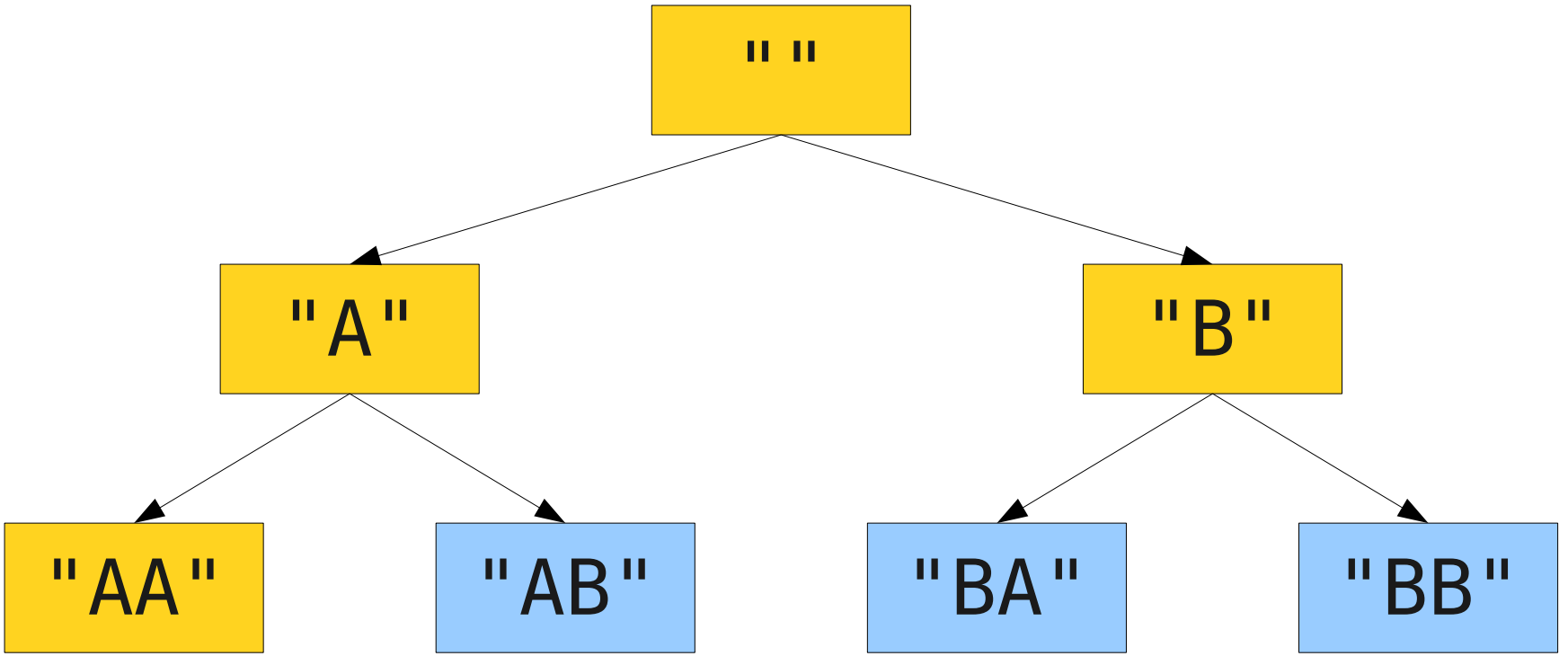

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

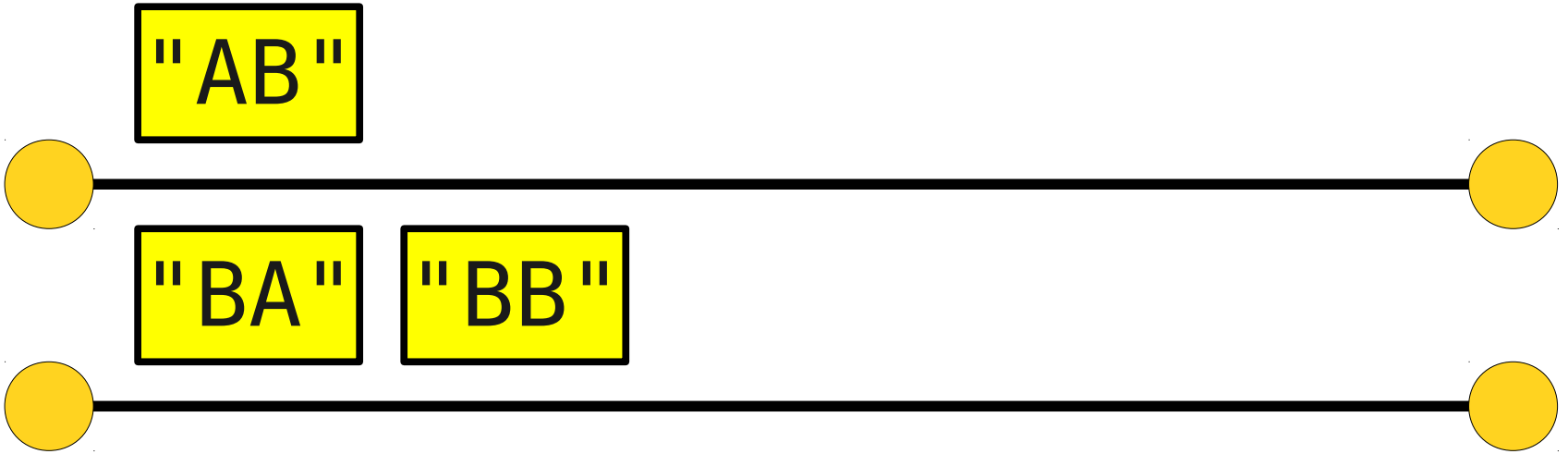

"AA"
"AB"
"BA"
"BB"

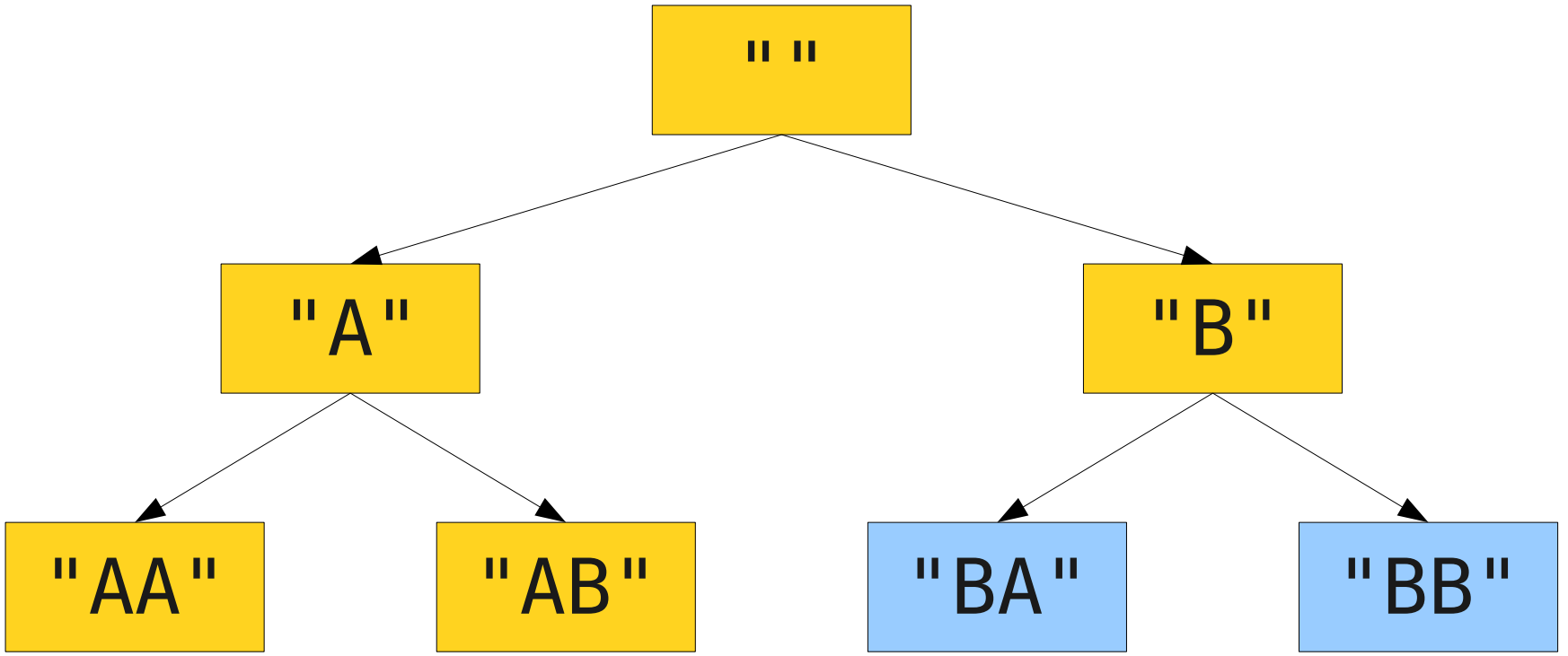

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

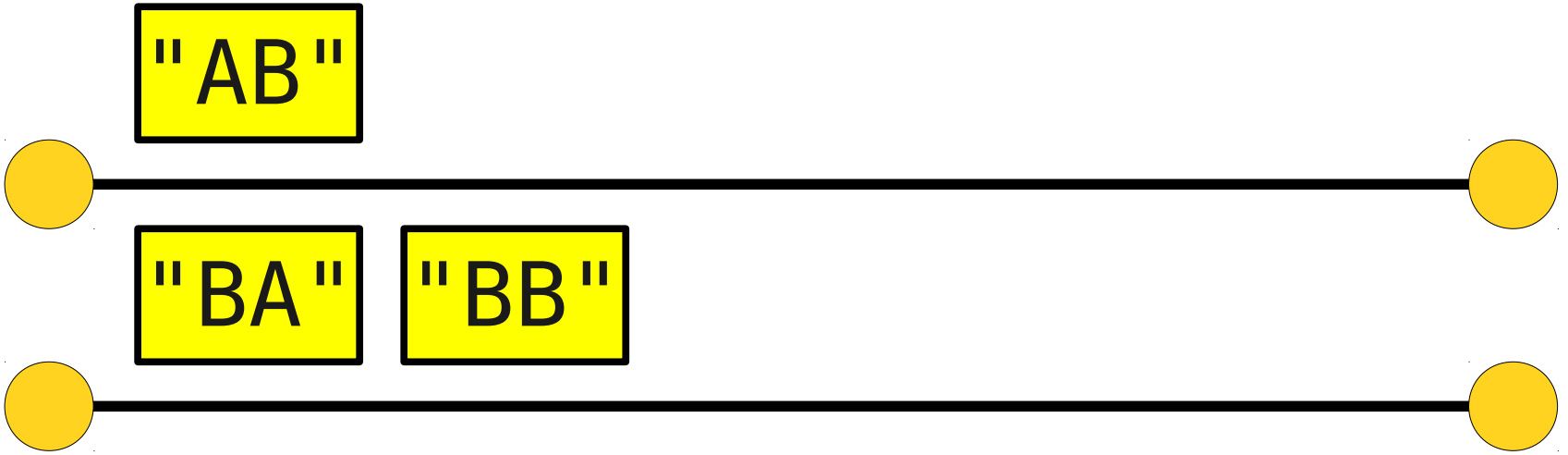

"AA"
"AB"
"BA"
"BB"

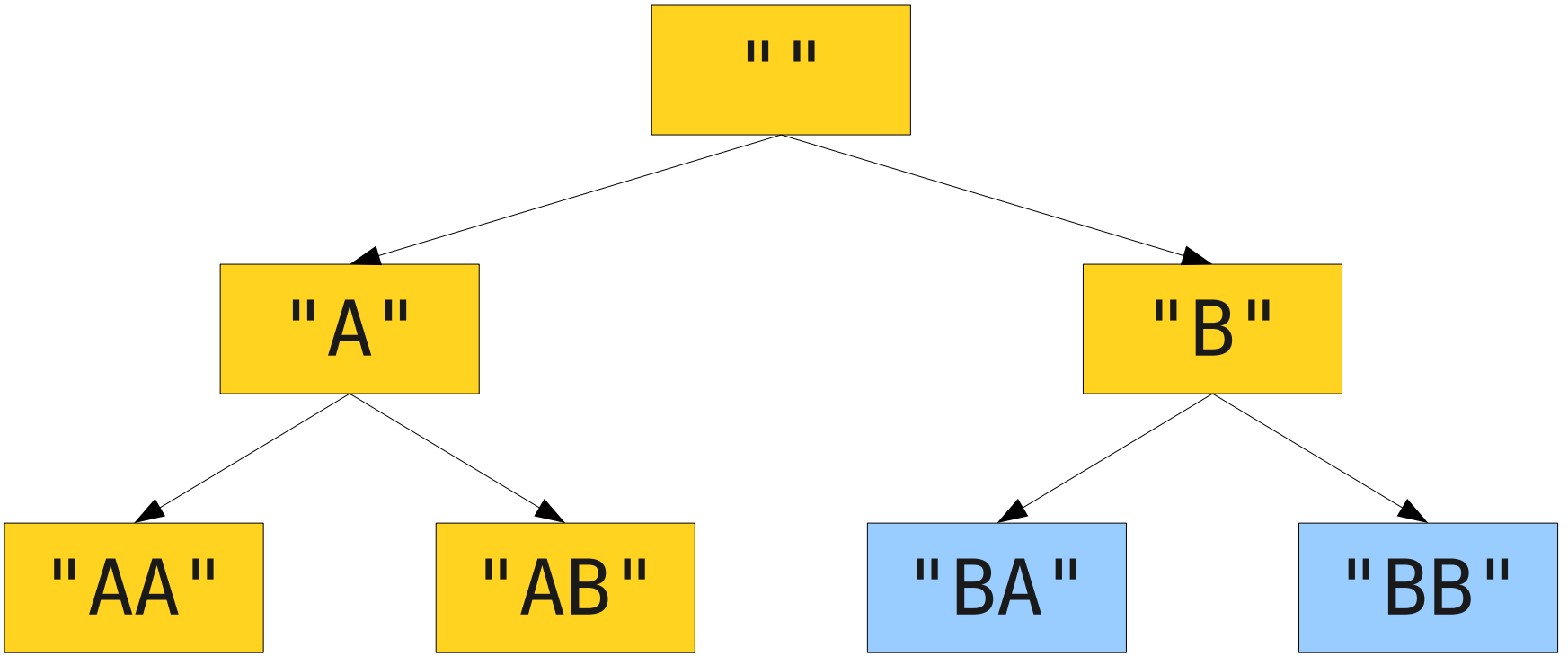

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"
"AB"
"BA"
"BB"

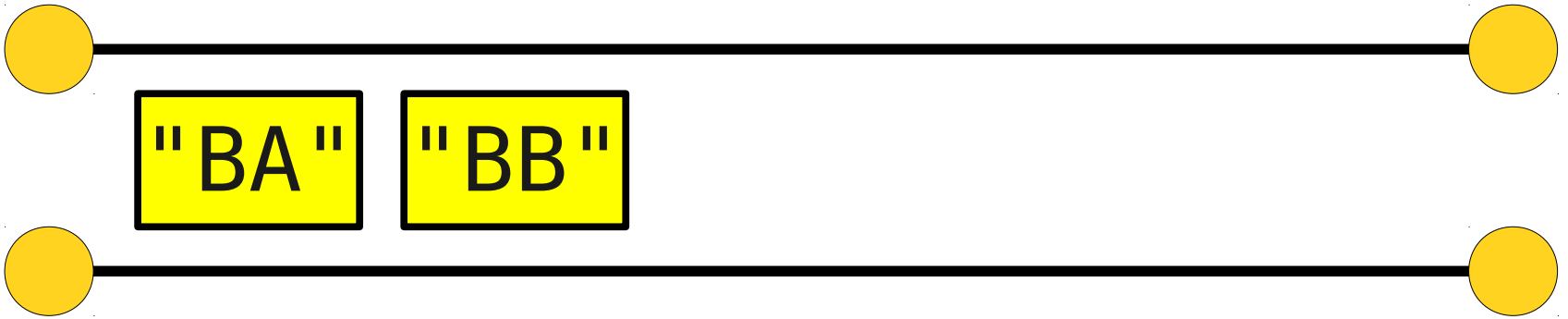

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

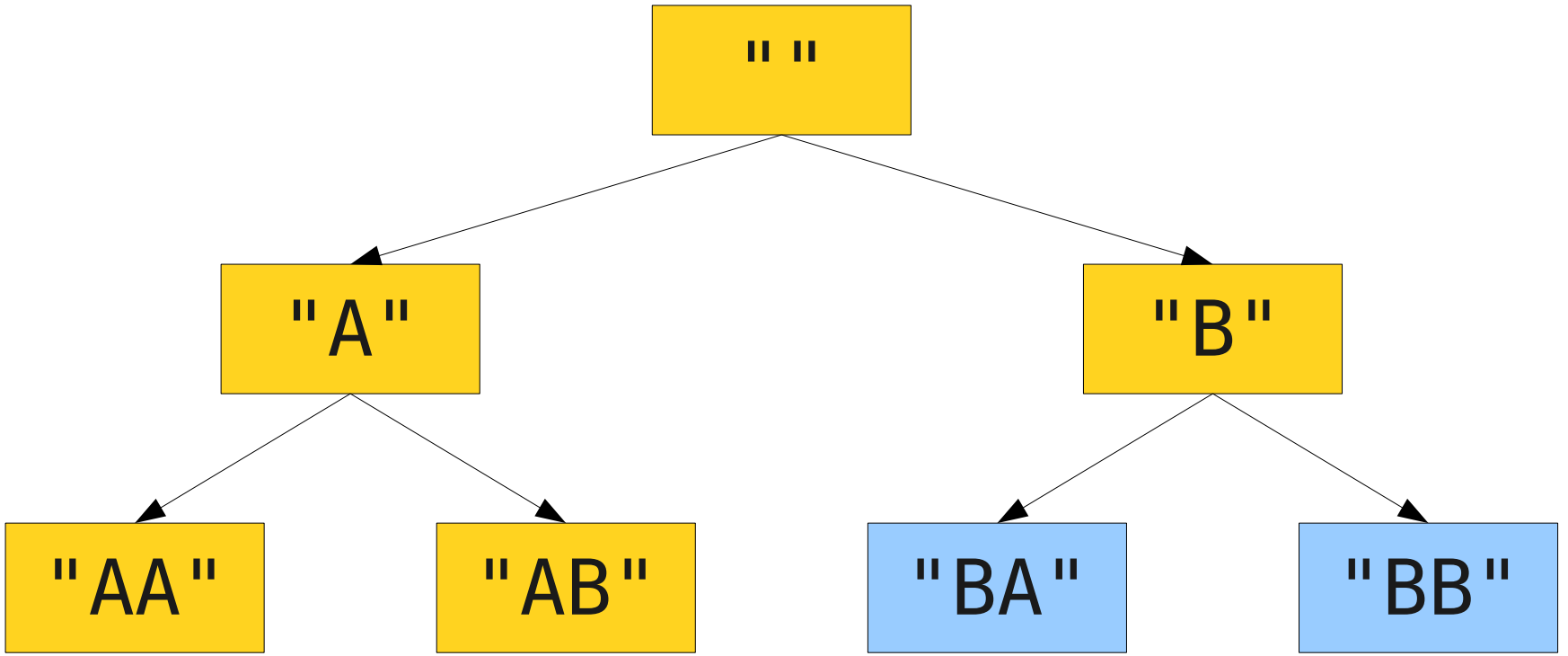

"AB"
"BA"
"BB"

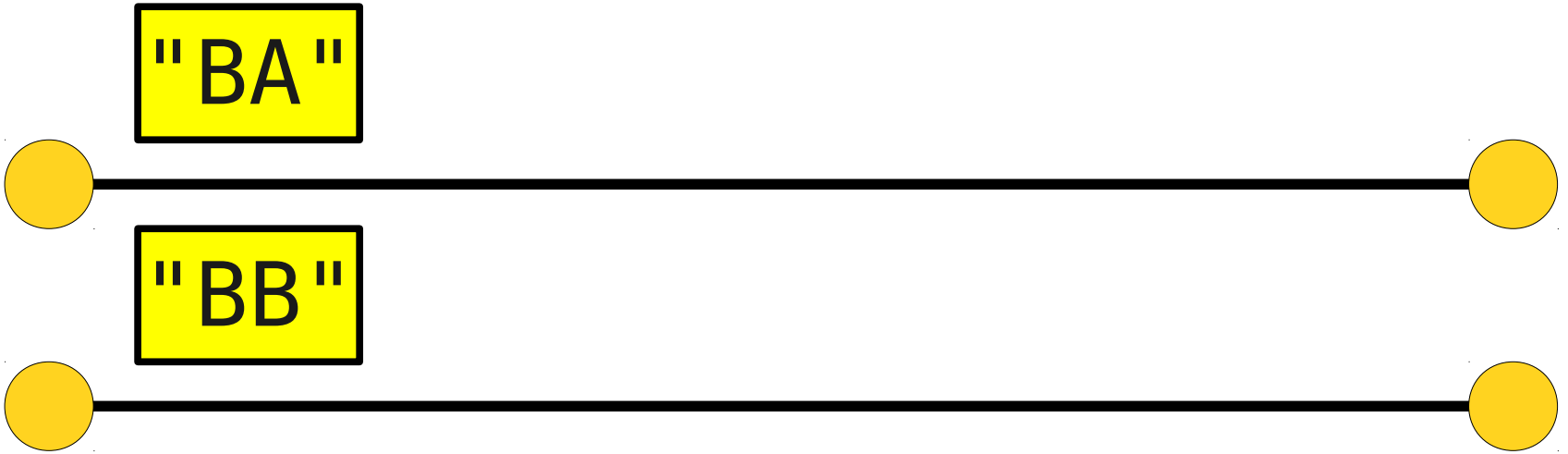

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

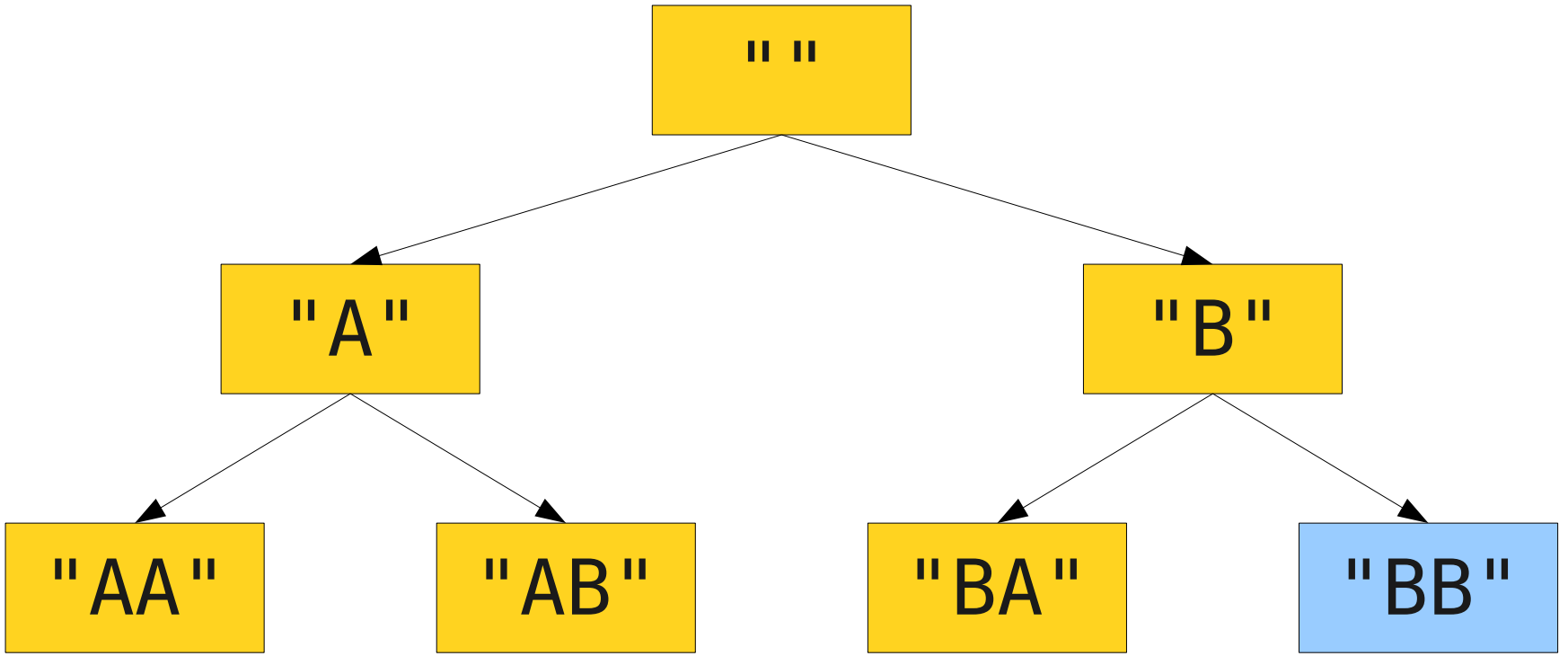

"AB"
"BA"
"BB"

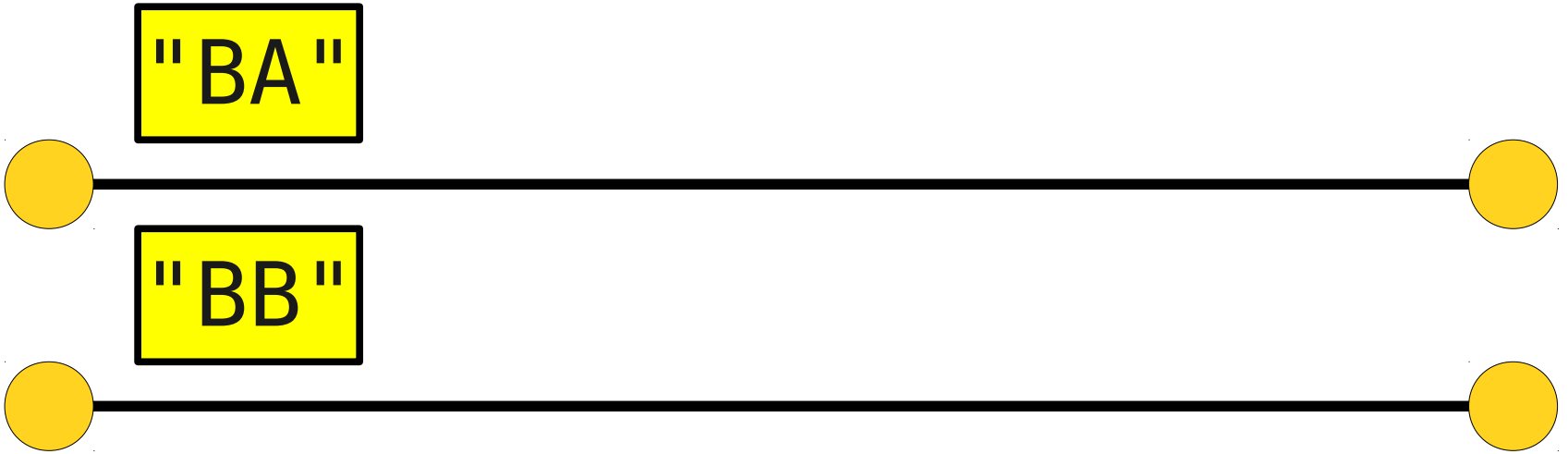

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

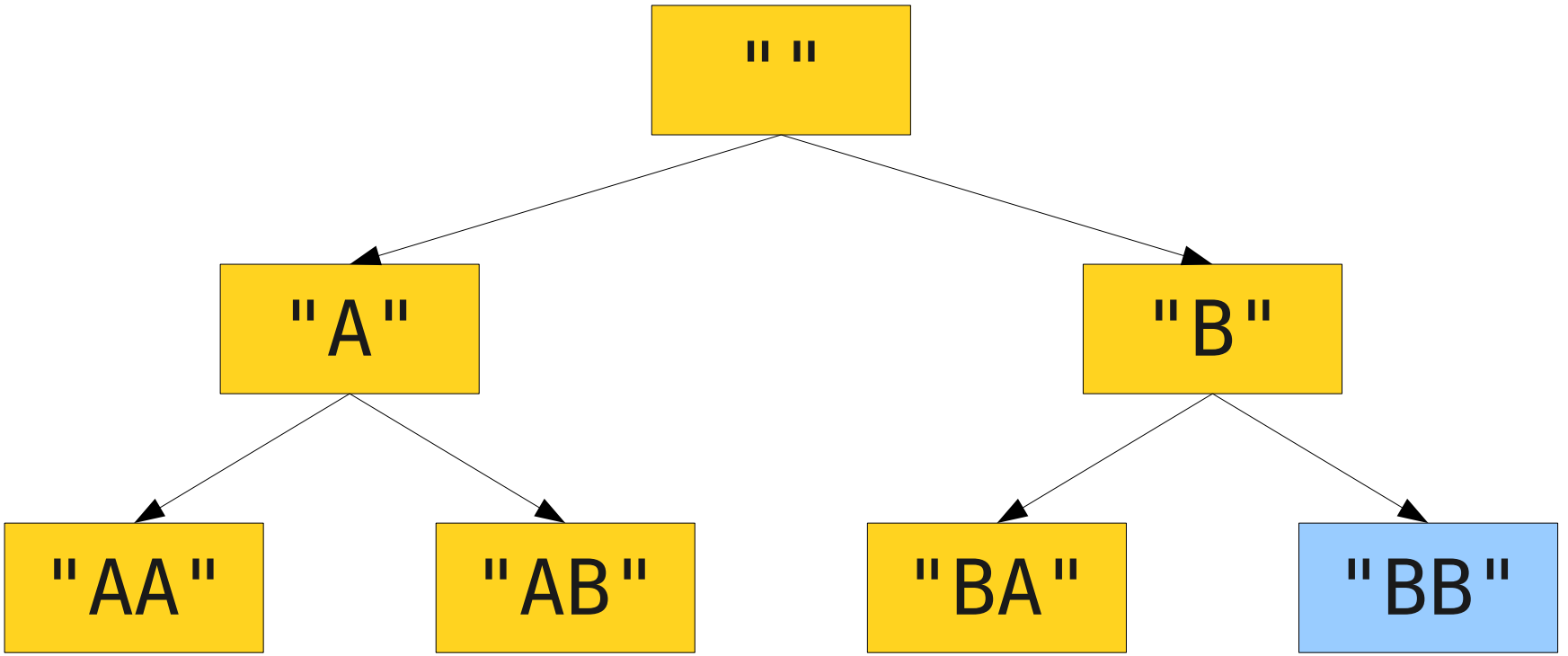

"BA"
"BB"


" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

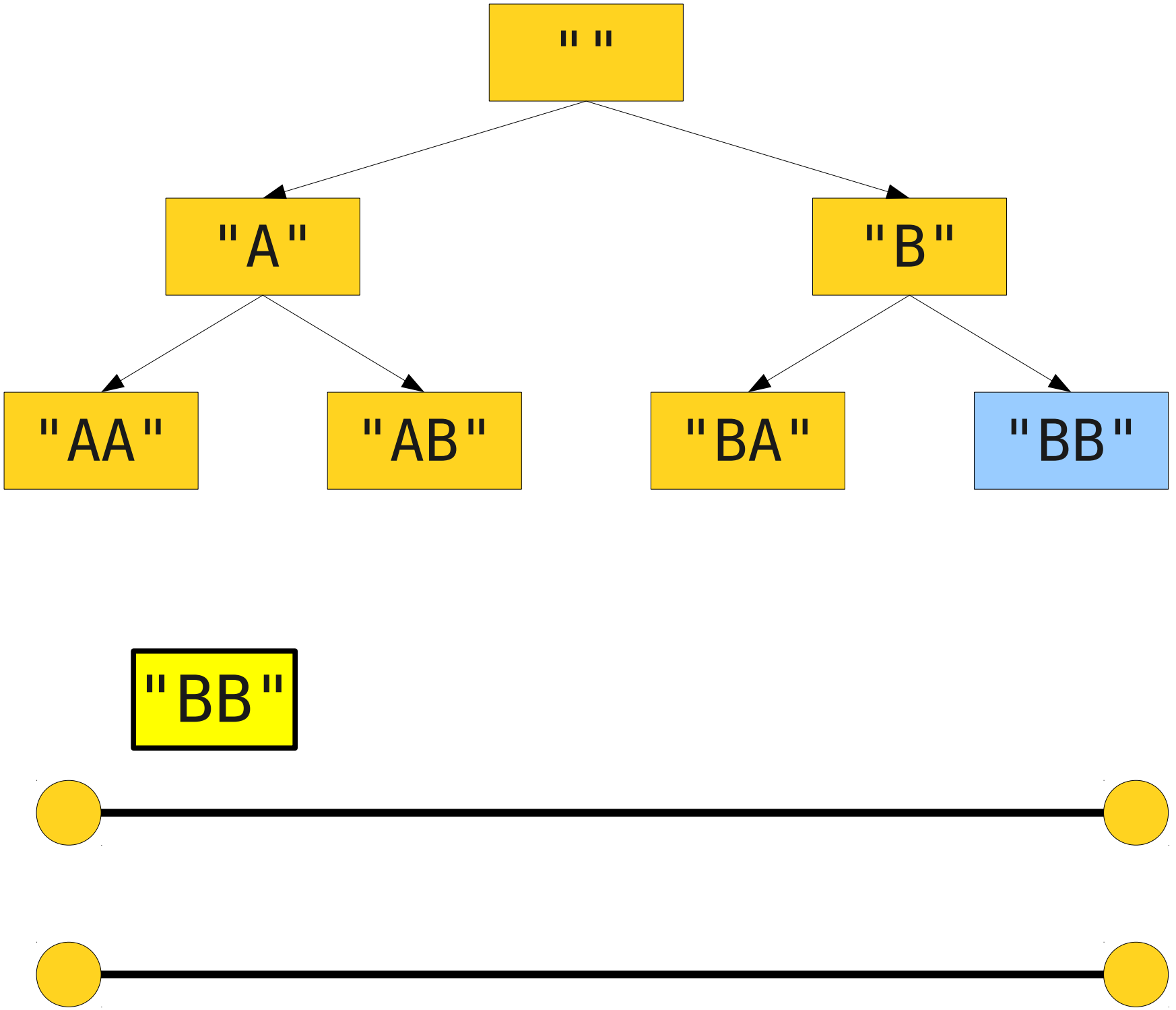

"BA"
"BB"

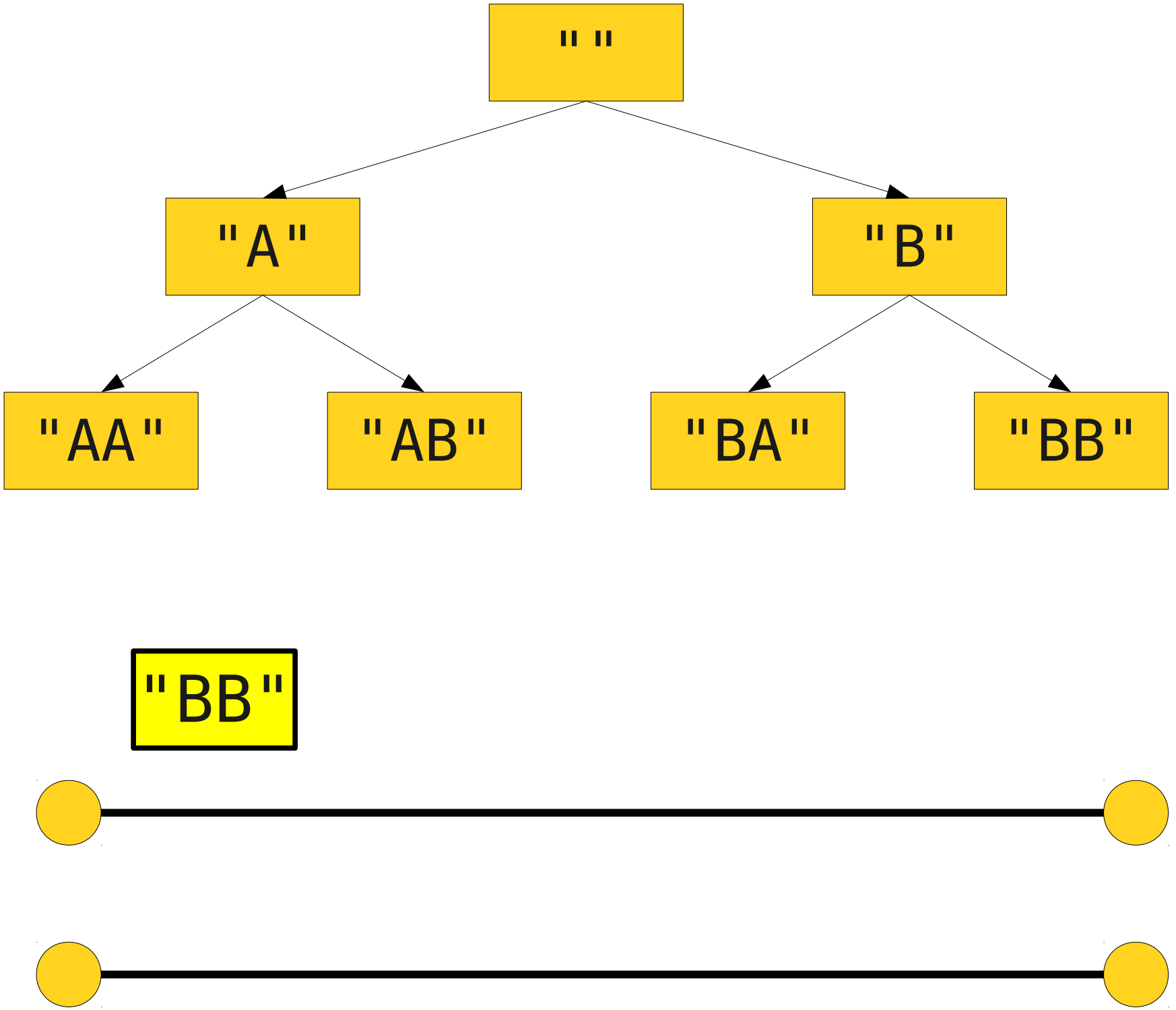

" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

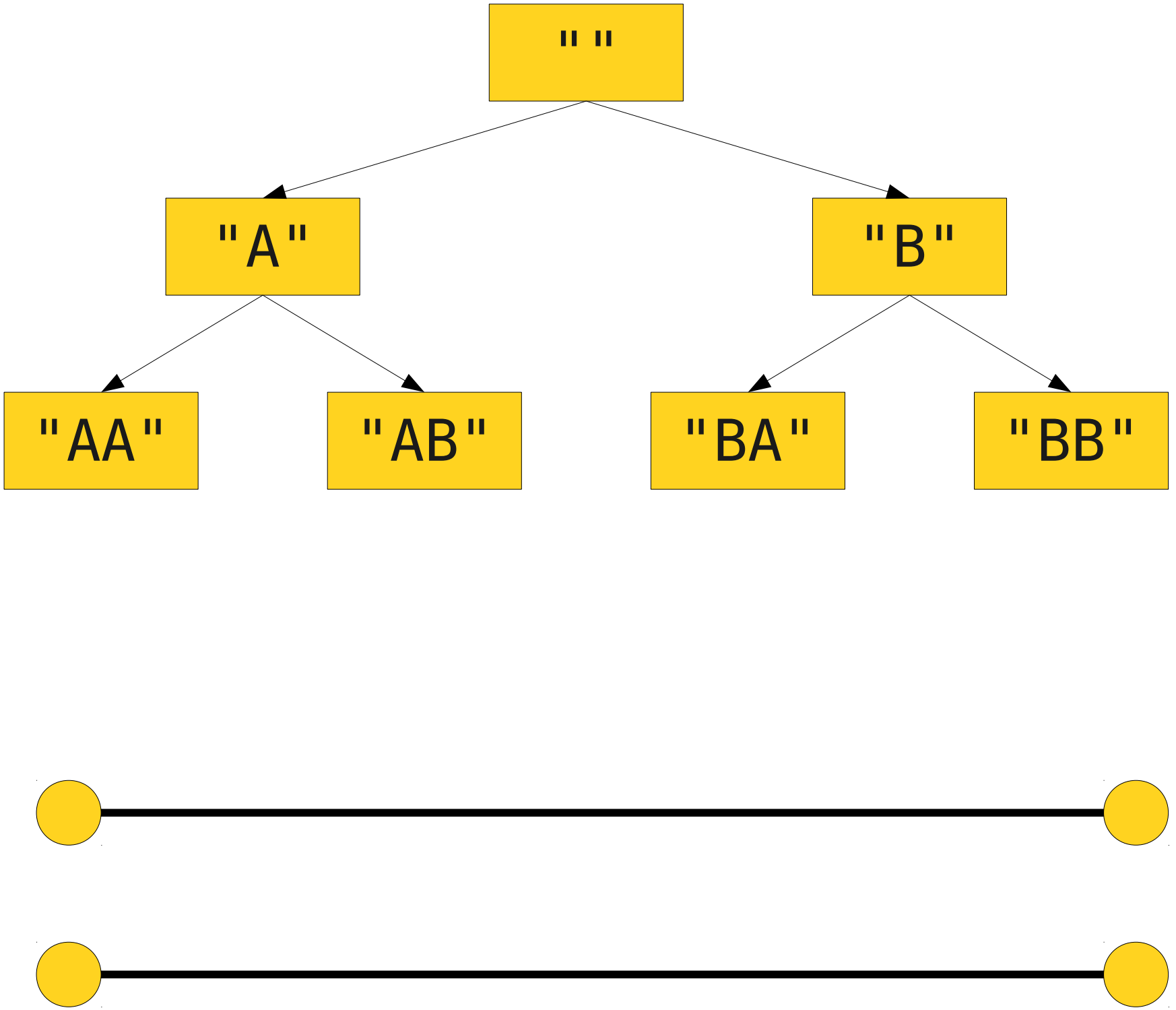

"BA"
"BB"


" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"


"BB"


" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"
"BB"


" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"
"BB"


" "
"A"
"B"
"AA"
"AB"
"BA"
"BB"

How to Remember All This?

An Amazingly Useful Link

http://www.stanford.edu/class/cs106b/materials/cppdoc/

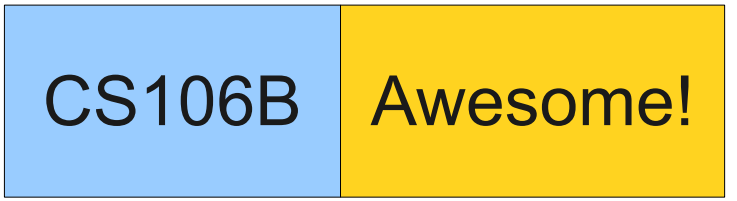
Map

Map

- The **`Map`** class represents a set of key/value pairs.
- Each key is associated with a unique value.
- Given a key, can look up the associated value.

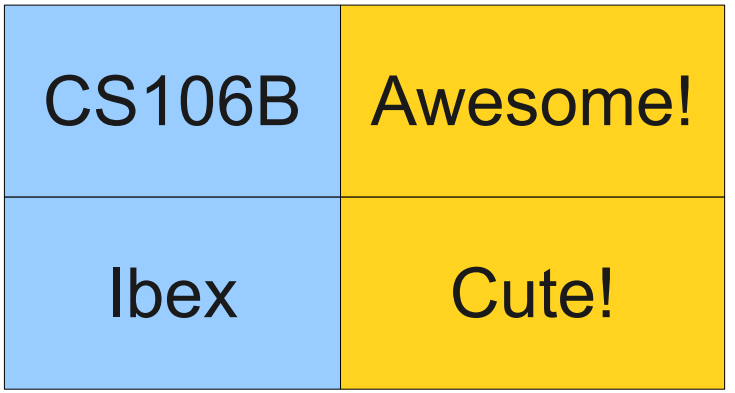
Map

- The **`Map`** class represents a set of key/value pairs.
- Each key is associated with a unique value.
- Given a key, can look up the associated value.



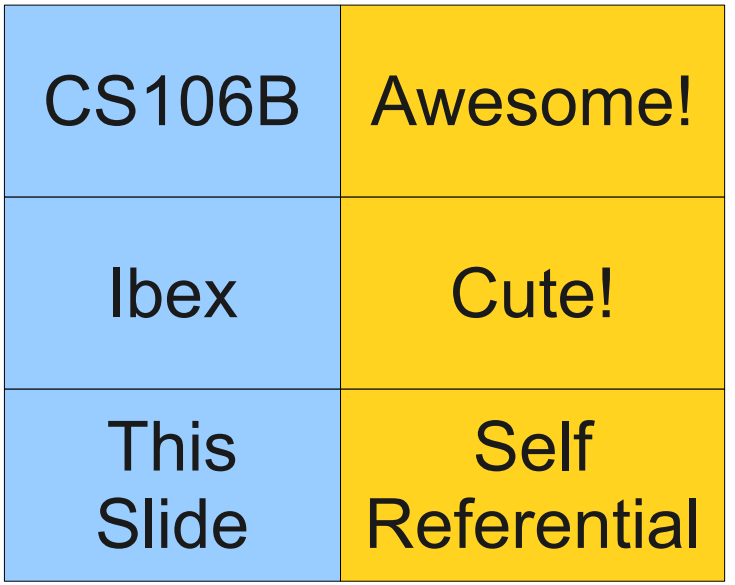
Map

- The **`Map`** class represents a set of key/value pairs.
- Each key is associated with a unique value.
- Given a key, can look up the associated value.



Map

- The **`Map`** class represents a set of key/value pairs.
- Each key is associated with a unique value.
- Given a key, can look up the associated value.



Map

- The **`Map`** class represents a set of key/value pairs.
- Each key is associated with a unique value.
- Given a key, can look up the associated value.

CS106B	Awesome!
Ibex	**Very** Cute!
This Slide	Self Referential

Using the Map

- To use the map, you must specify both the key type and the value type:

```
Map<KeyType, ValueType> map;
```

- You can add or change a key/value pair by writing

```
map[key] = value;
```

- You can read the value associated with a key by writing

```
map[key]
```

  If no value exists, a new key/value pair is automatically added for you. The value is initialized to a sensible default.

- You can check whether a key exists in the map by calling

```
map.containsKey(key)
```

What states have the most cities/towns in them?

What states have the fewest?

foreach

- You can loop the elements of any collection class using the **foreach** macro:

```
foreach (type var in collection) {
    /* … do something with var … */
}
```

- **foreach** is **not** a part of standard C++; it's a *macro* that we've built to keep things simple.
- Oh, and the implementation of **foreach** will make you go blind. You've been warned.

Ordering in `foreach`

- When using `foreach` to iterate over a collection:
  - In a **`Vector`**, **`string`**, or array, the elements are retrieved in order.
  - In a **`Map`**, the *keys* are returned in sorted order.
  - In a **`Set`** or **`Lexicon`** (more on them later), the values are returned in sorted order.
  - In a **`Grid`**, the elements of the first row are returned in order, then the second row, etc. (this is called *row-major order*).