Tail call optimization

tail call optimization for writing elegant recursive solutions without the performance tax of ES5

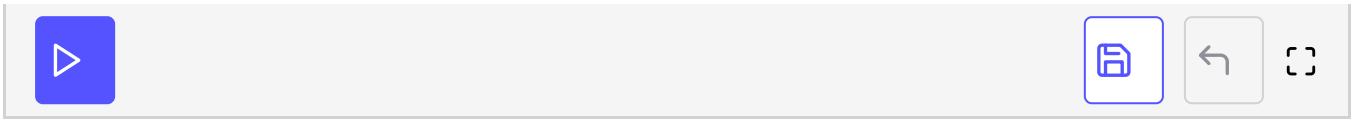
A tail call is a subroutine call performed as the final action of a procedure. That is,

```
return myFunction()
```

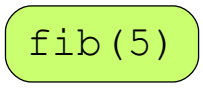
It is important to understand that ES6 does not introduce new syntax for tail call optimization. It is just a different structure of code to make sure that it is efficient.

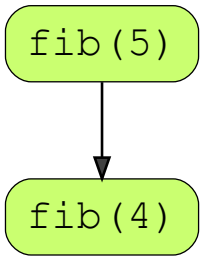
Let’s calculate the Fibonacci using recursion:

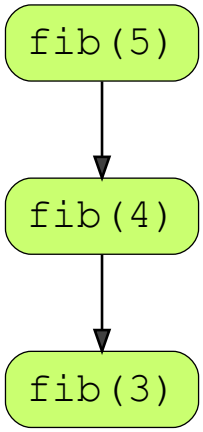
```
function fib(n) {
  if (n <= 1){
    return n;
  } else {
    return fib(n-1) + fib(n - 2);
  }
}
```

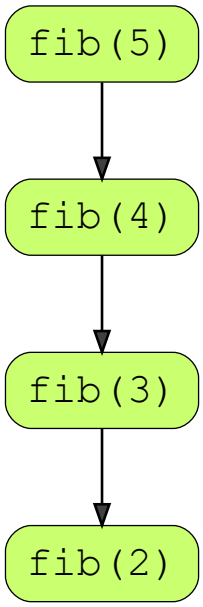


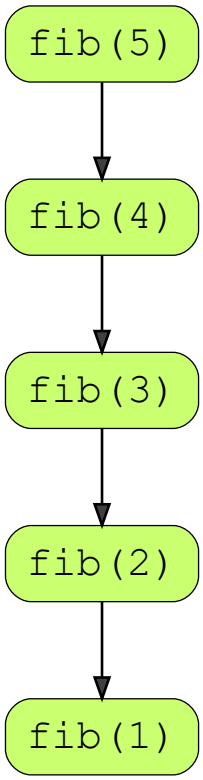
Let’s view the function calls in the form of a tree:

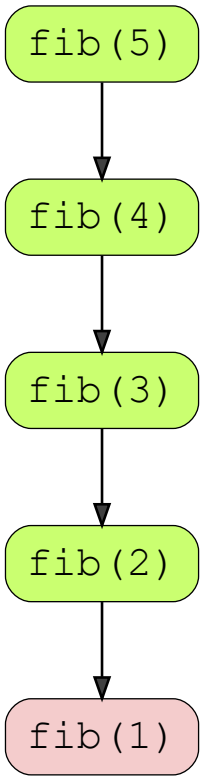

fib(5)

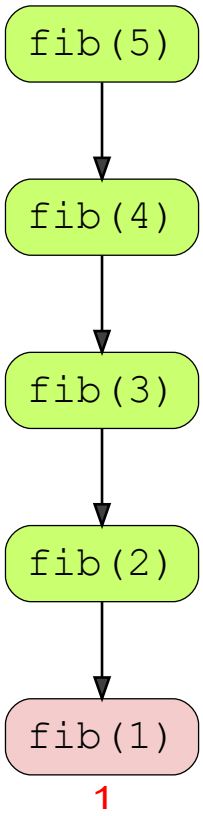

fib(5)
fib(4)

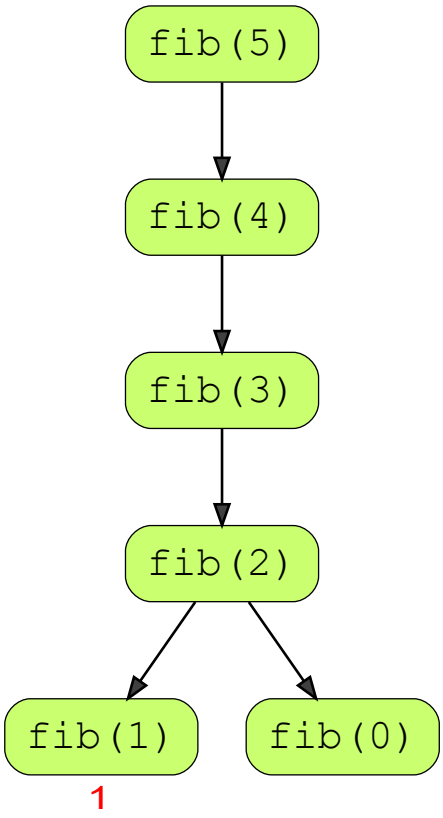

fib(5)
fib(4)
fib(3)

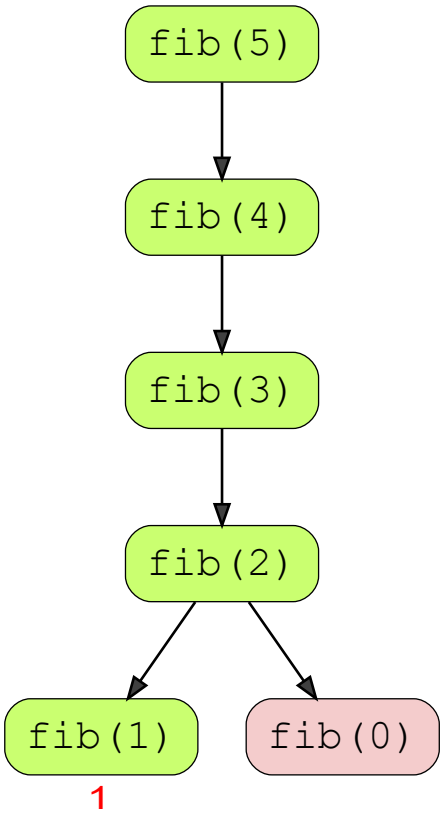

fib(5)
fib(4)
fib(3)
fib(2)

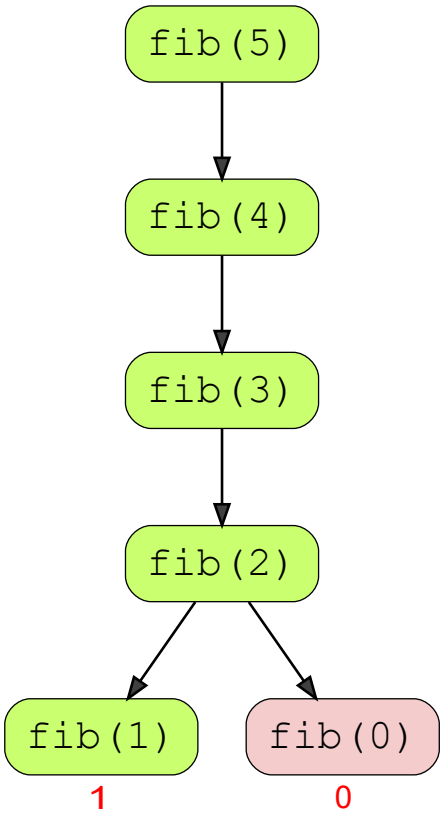

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)

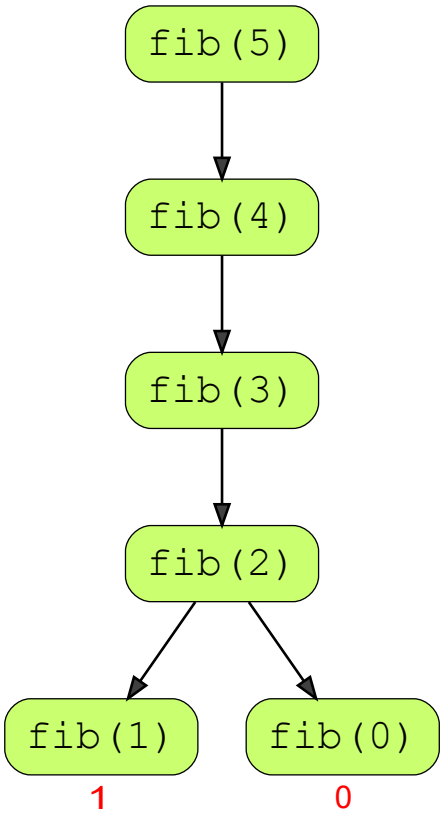

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)

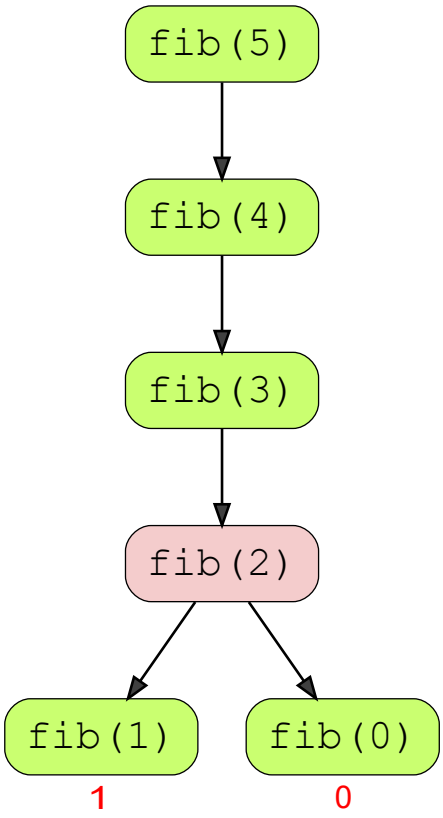

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
1

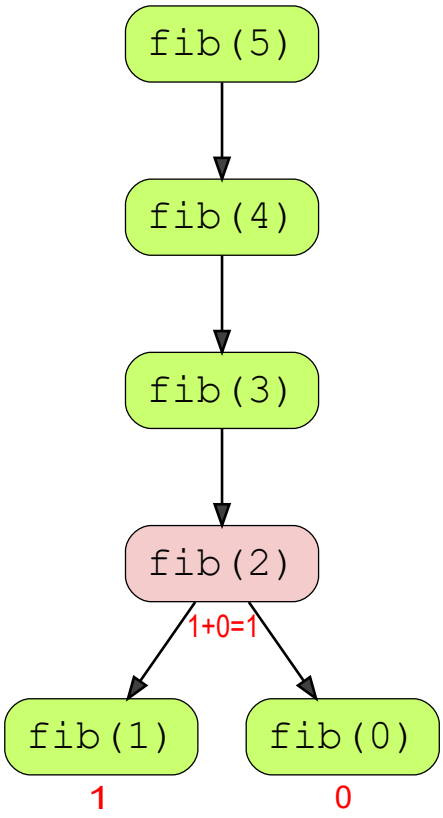

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
fib(0)
1

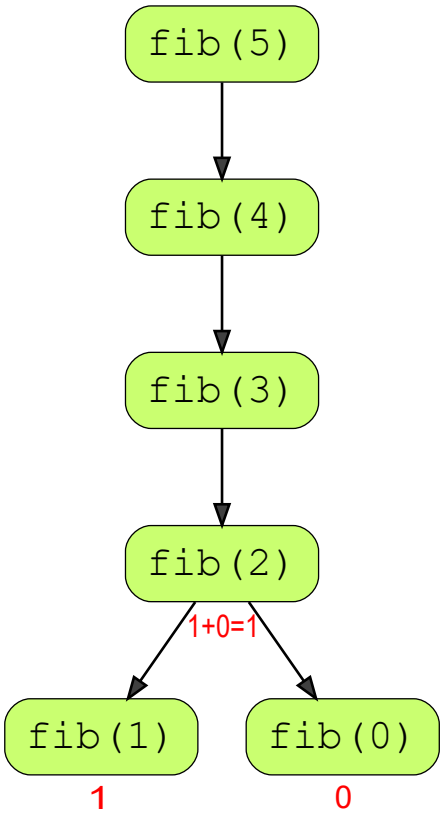

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
fib(0)
1

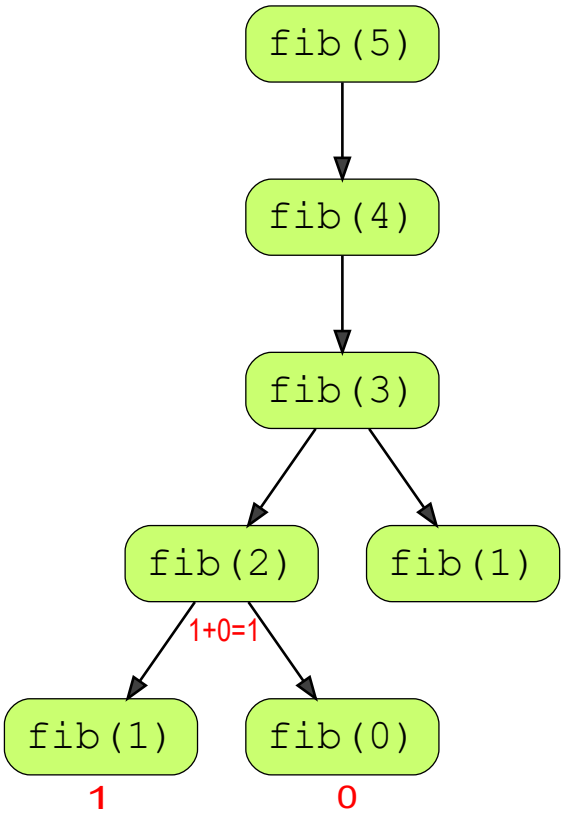

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
fib(0)
1
0

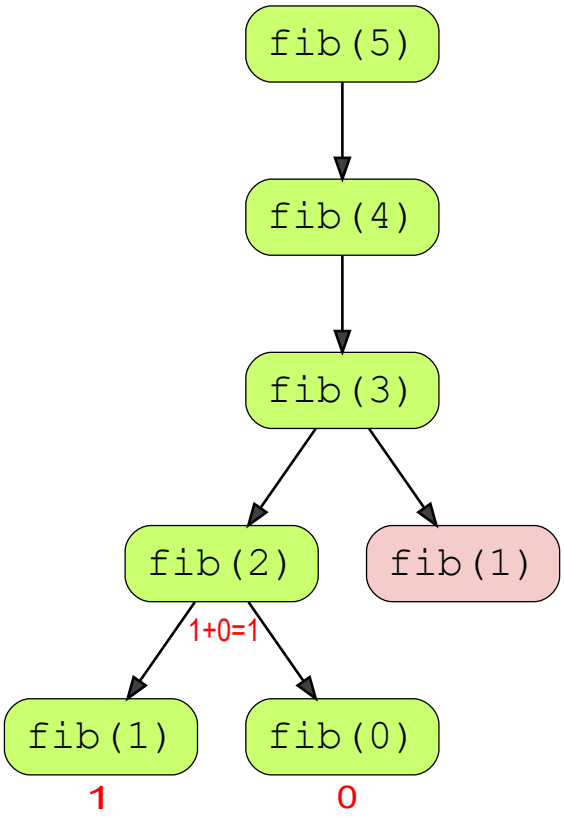

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
fib(0)
1
0

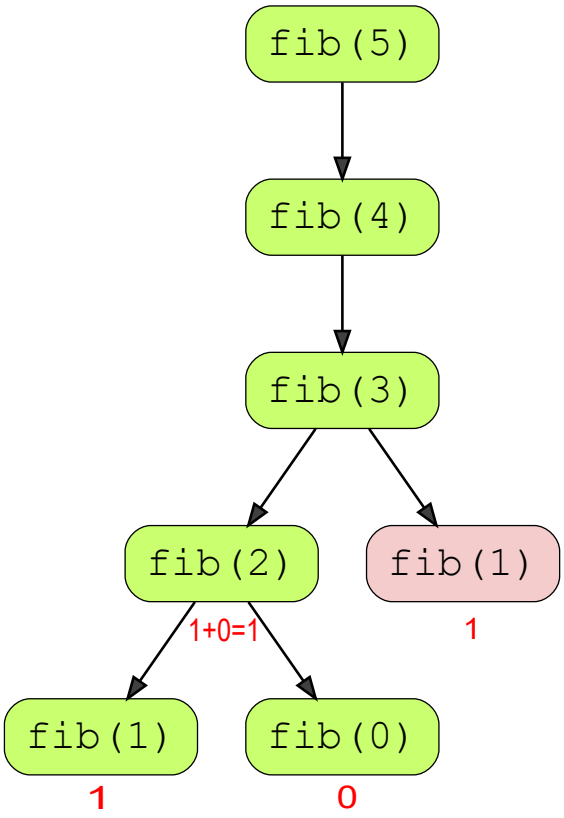

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
fib(0)
1
0

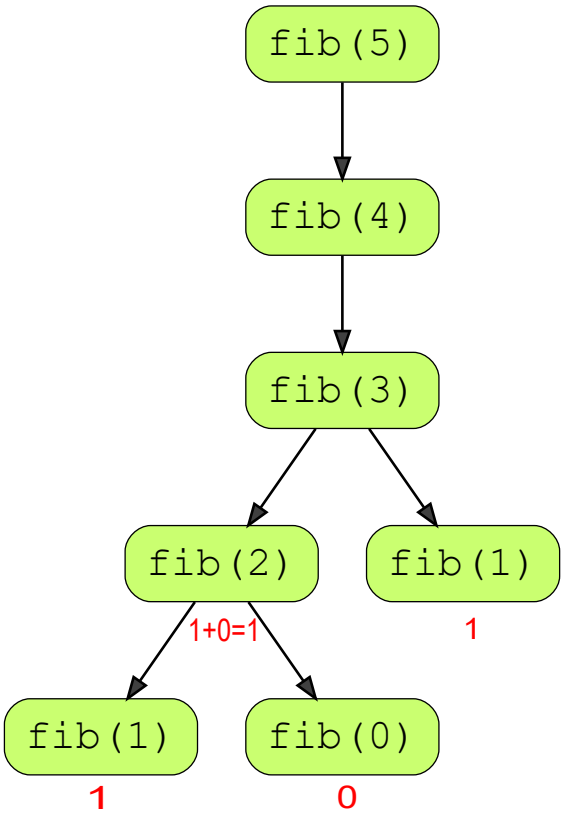

fib(5)
fib(4)
fib(3)
fib(2)
1+0=1
fib(1)
fib(0)
1
0

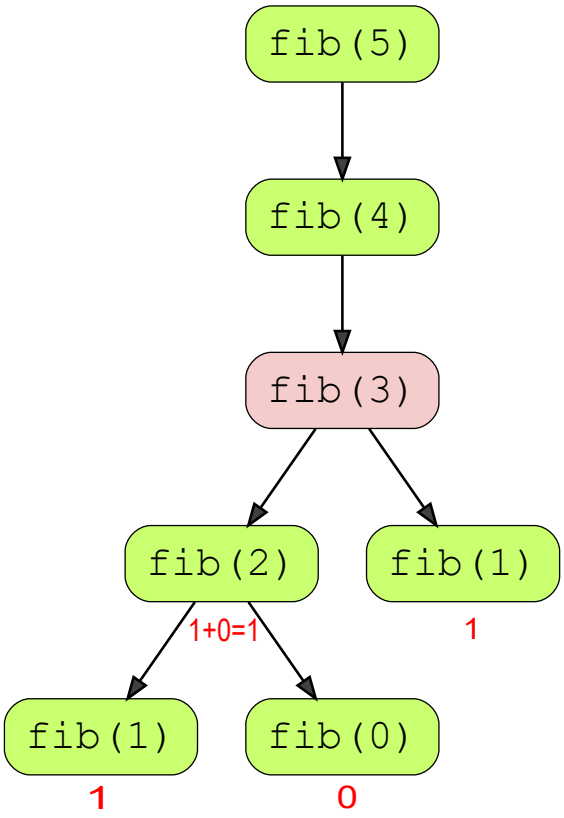

fib(5)
fib(4)
fib(3)
fib(2)
1+0=1
fib(1)
fib(0)
1
0

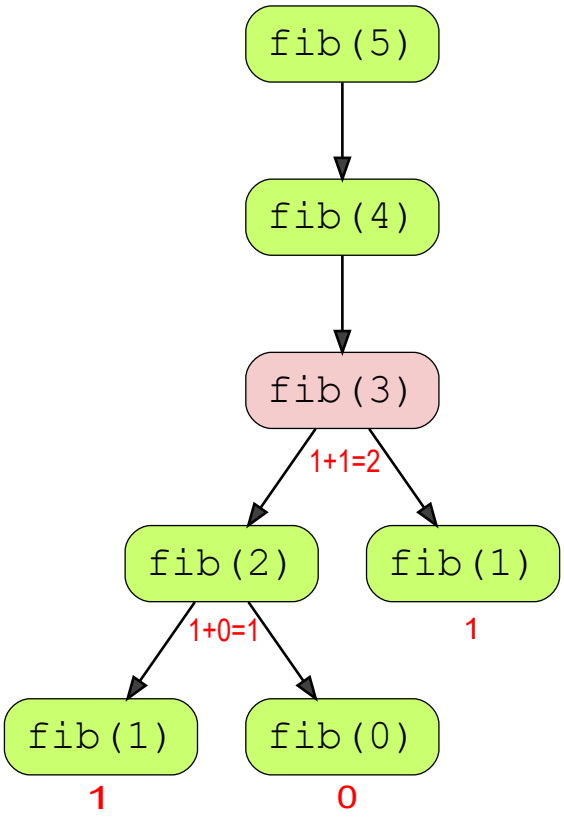

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
1+0=1
fib(1)
fib(0)
1
0

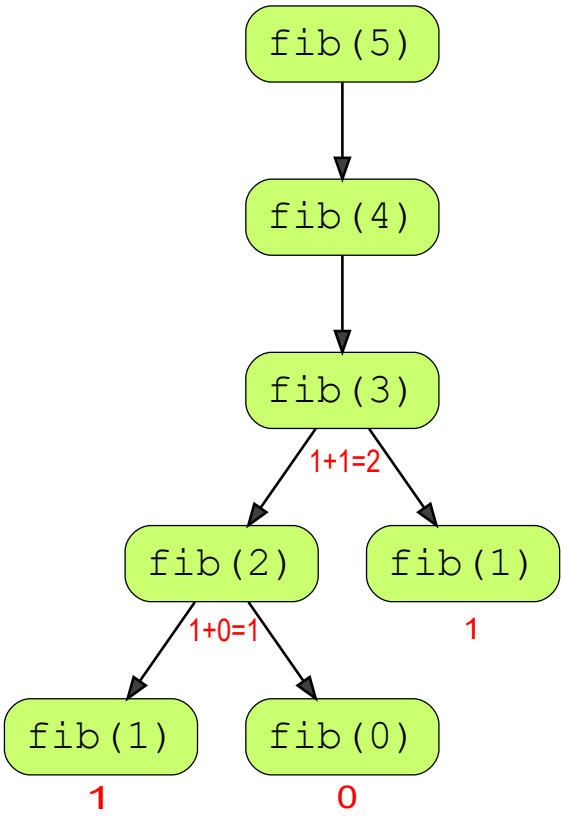

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
1+0=1
fib(1)
fib(0)
1
0

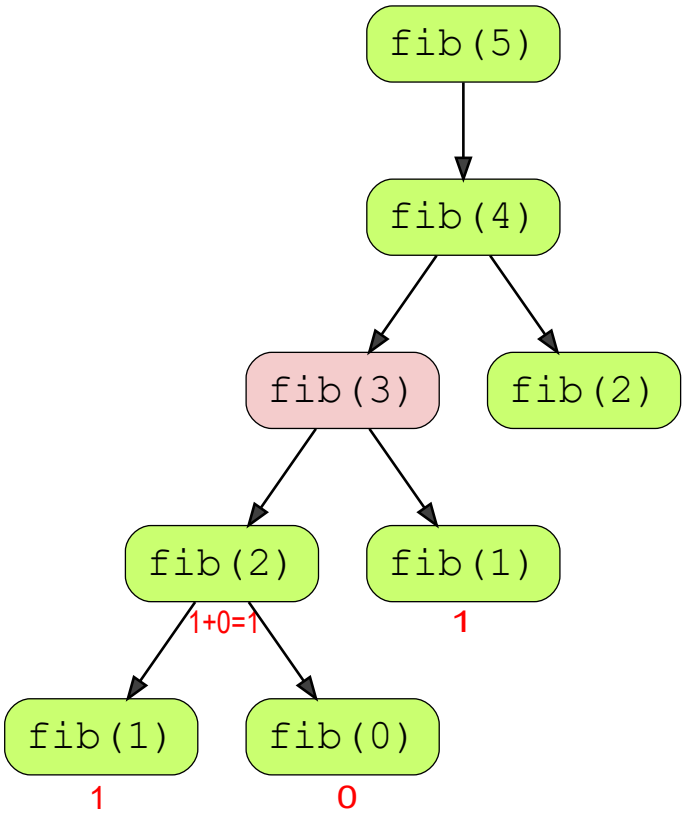

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
1+0=1
1
fib(1)
fib(0)
1
0

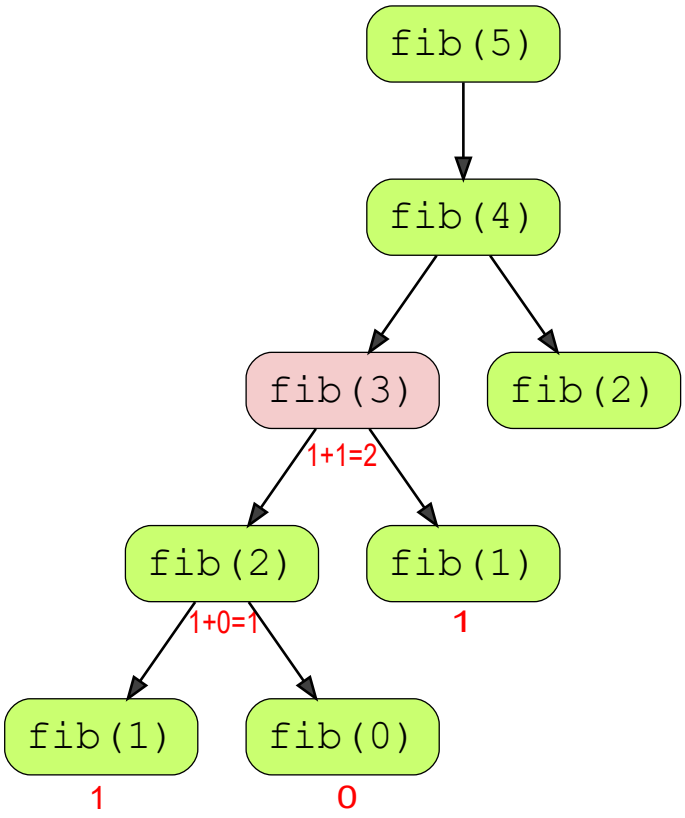

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
1+0=1
1
fib(1)
fib(0)
1
0

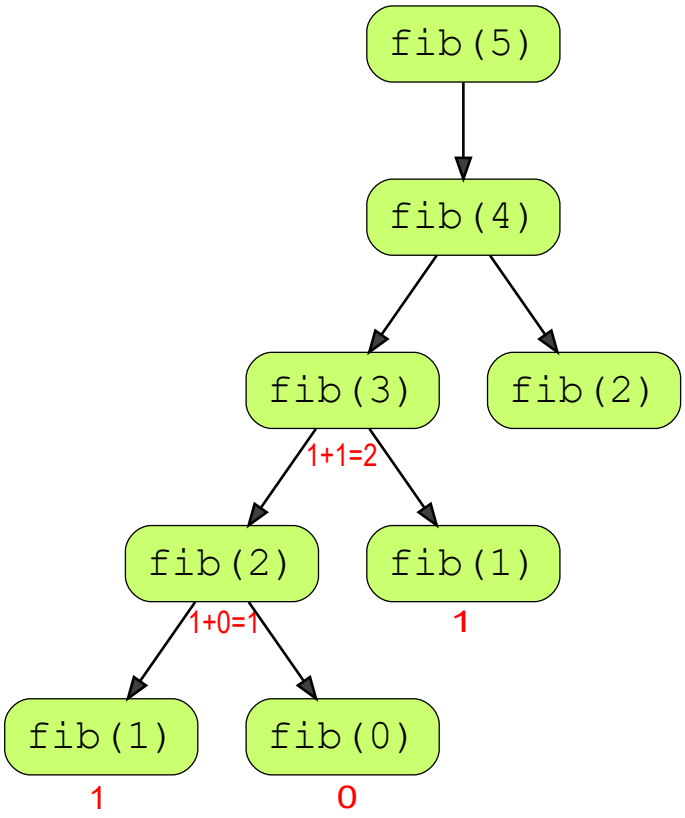

fib(5)
fib(4)
fib(3)
fib(2)
fib(1)
1+0=1
1
fib(1)
fib(0)
1
0

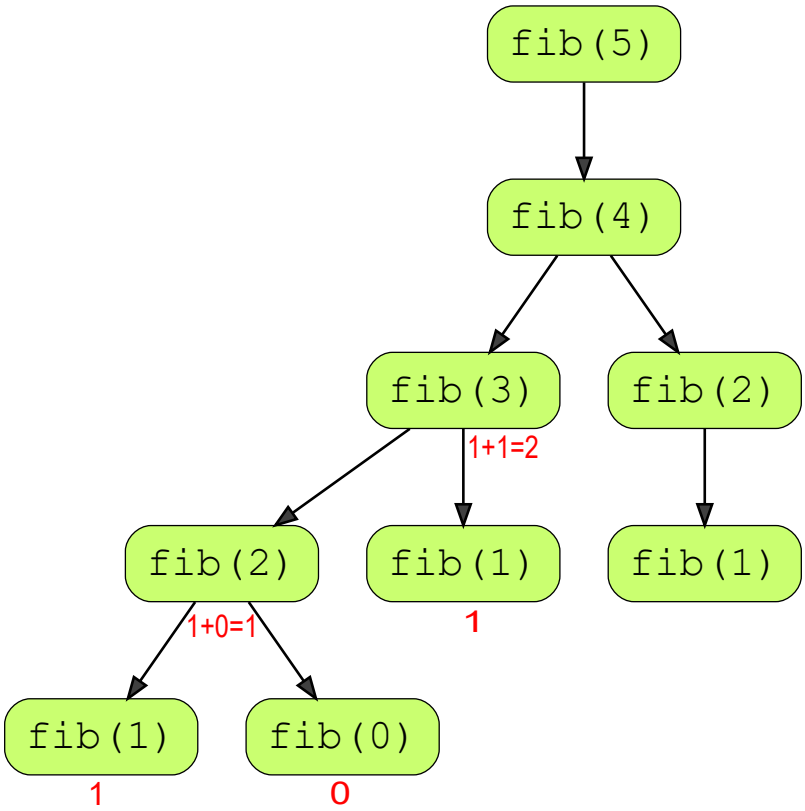

fib(5)
fib(4)
fib(3)
1+1=2
fib(2)
fib(1)
1
1+0=1
fib(1)
1
fib(0)
0

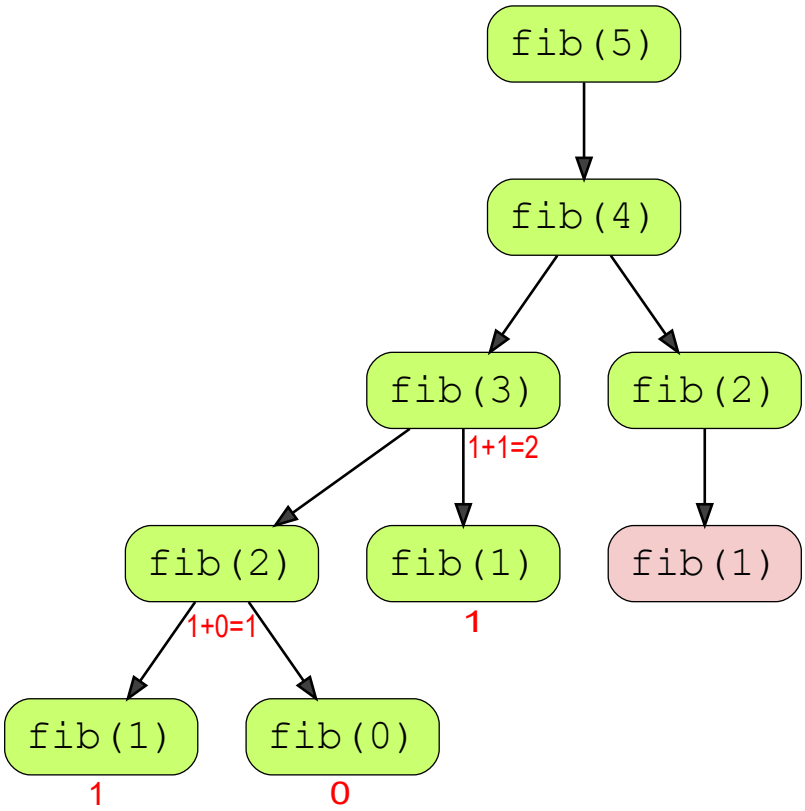

fib(5)
fib(4)
fib(3)
1+1=2
fib(2)
fib(1)
1+0=1
1
fib(1)
fib(0)
1
0

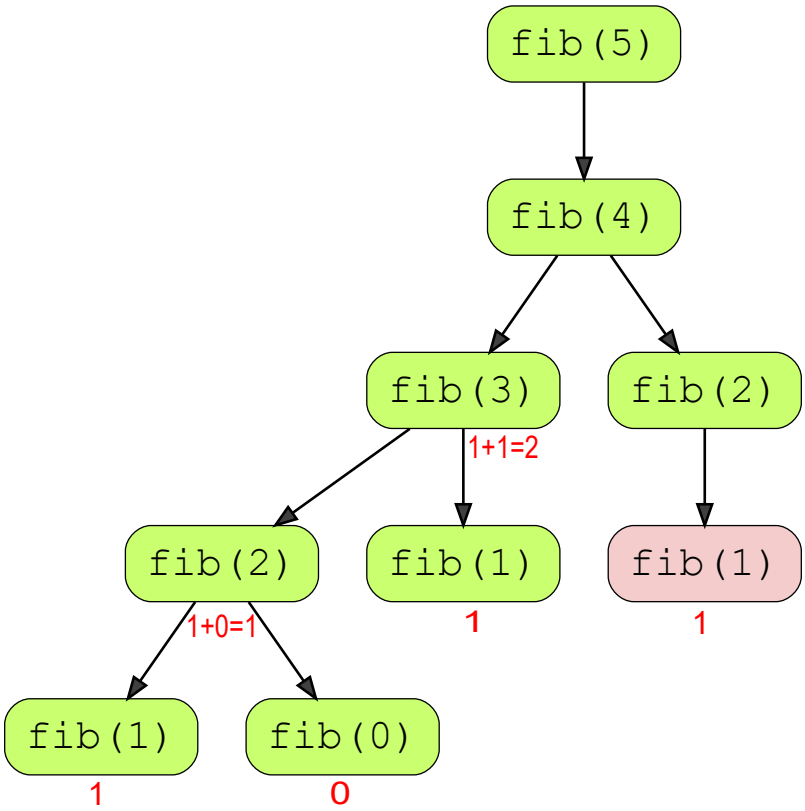

fib(5)
fib(4)
fib(3)
fib(2)
fib(2)
fib(1)
1+0=1
1
fib(1)
fib(0)
1
0

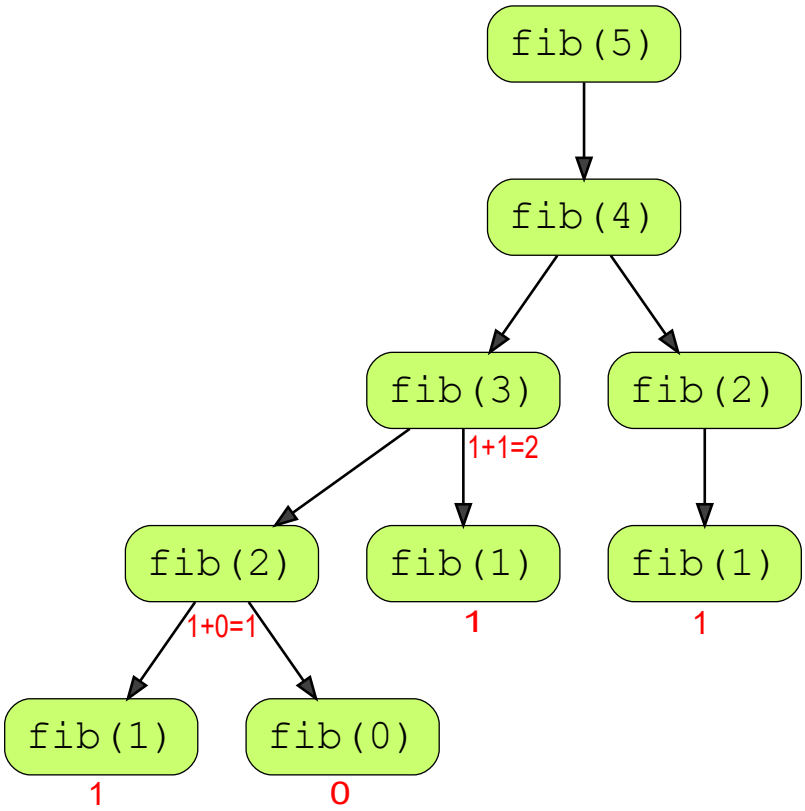

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
fib(2)
fib(1)
1
1+0=1
fib(1)
fib(0)
1
0

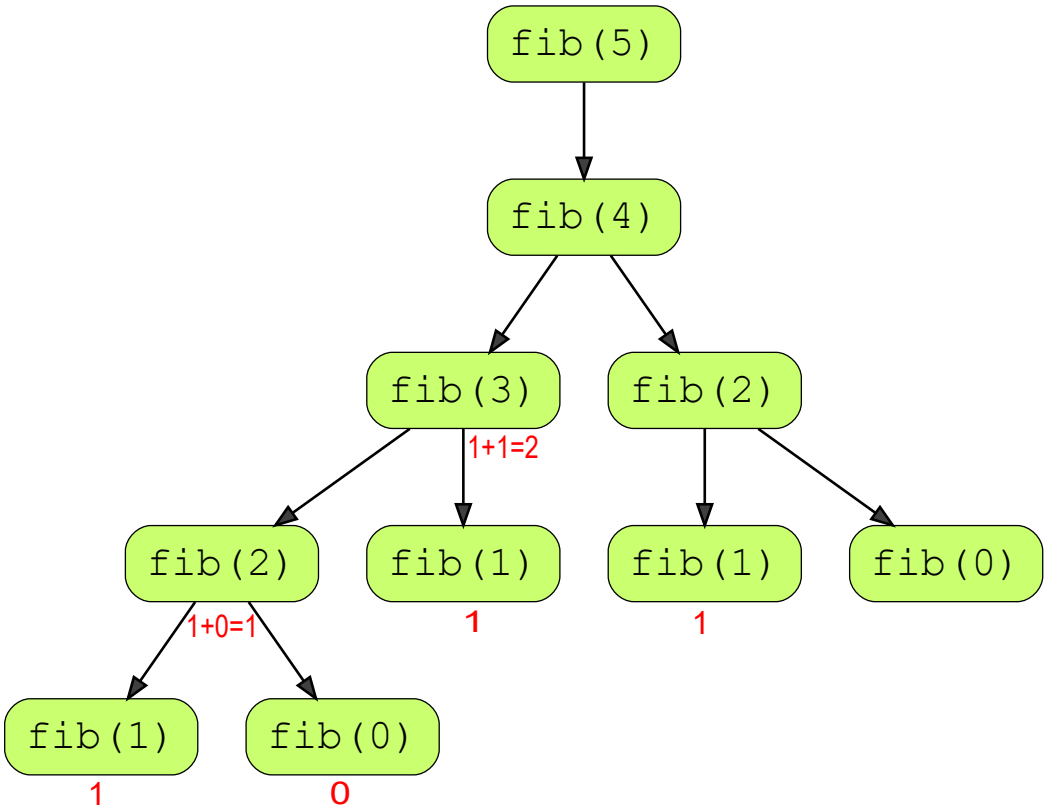

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
fib(2)
fib(1)
1
1+0=1
fib(1)
fib(0)
1
0

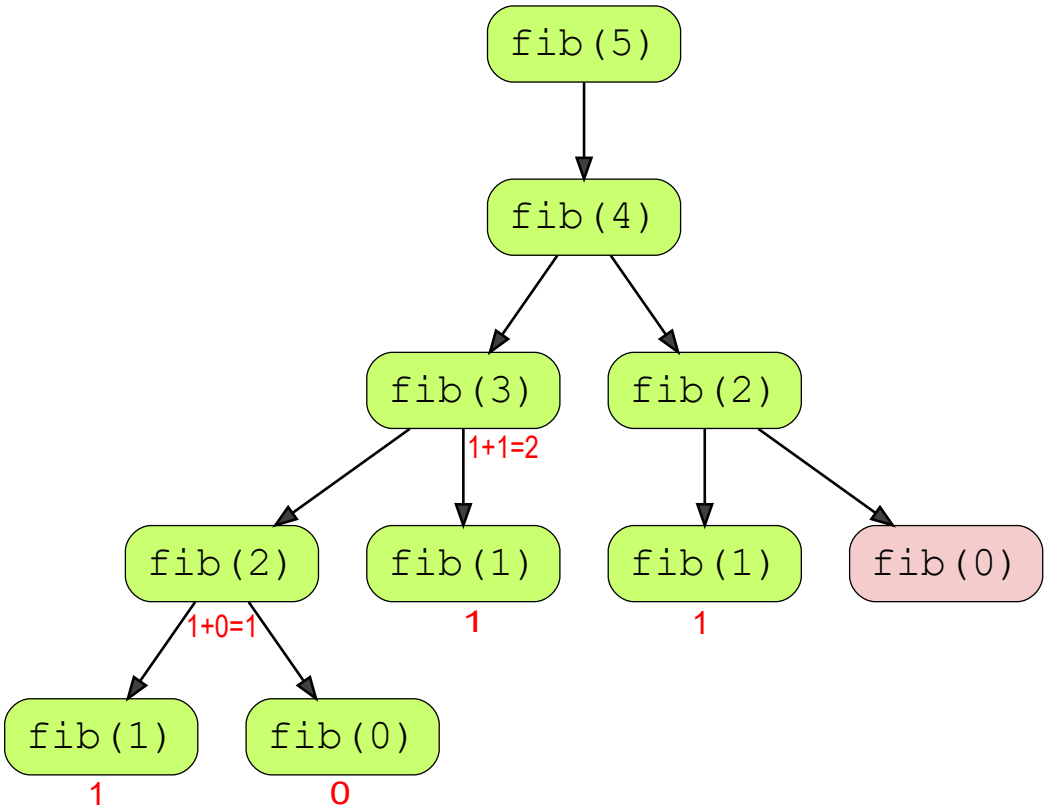

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
fib(2)
fib(1)
fib(1)
1
1+0=1
fib(1)
fib(0)
1
0

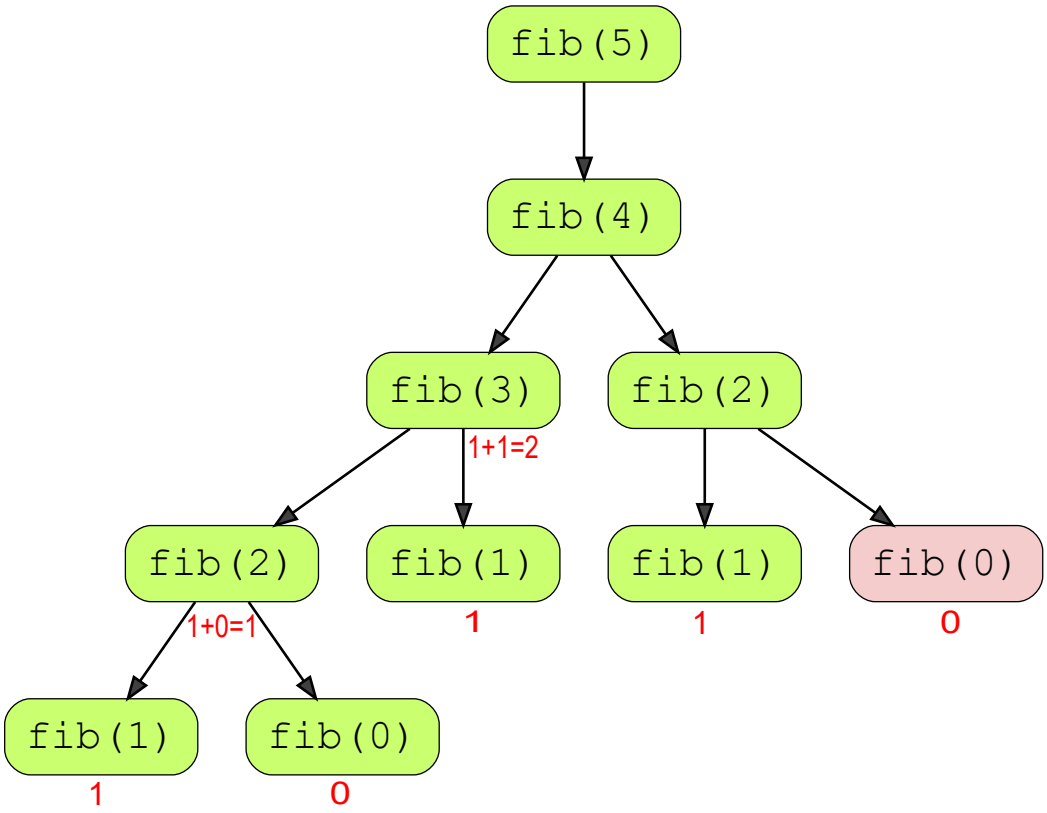

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
fib(2)
fib(1)
fib(1)
1+0=1
1
fib(1)
fib(0)
1
0

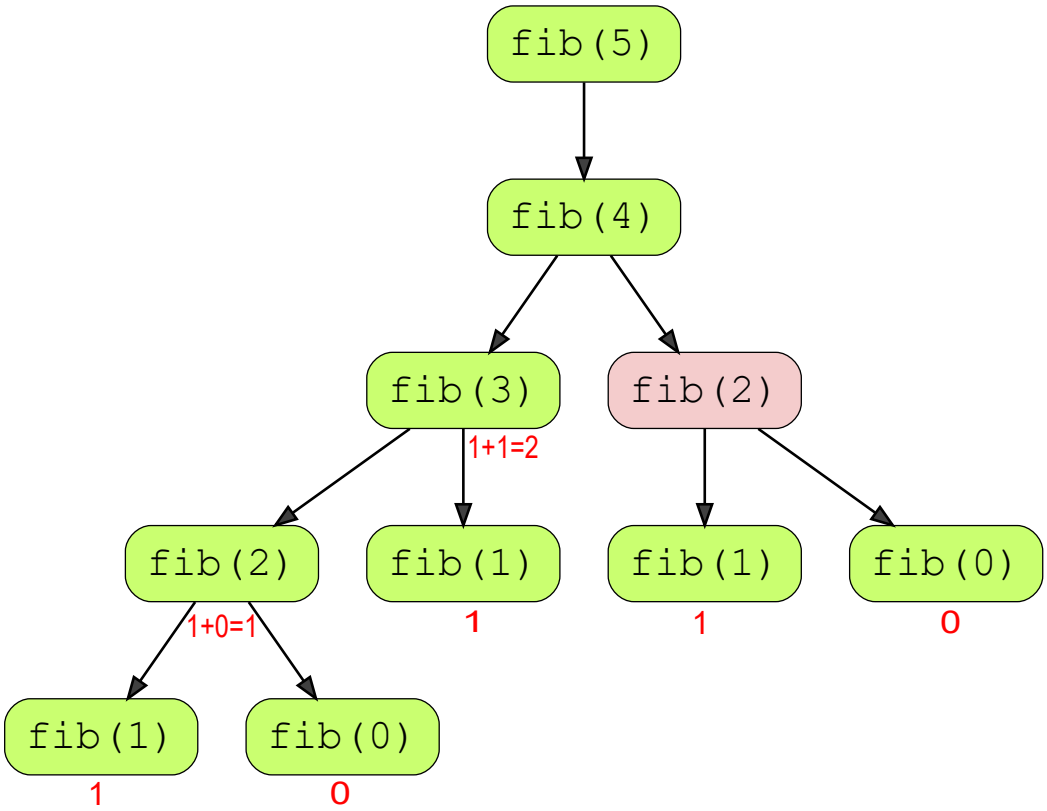

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
fib(2)
fib(1)
fib(1)
1
1
1+0=1
fib(1)
fib(0)
1
0

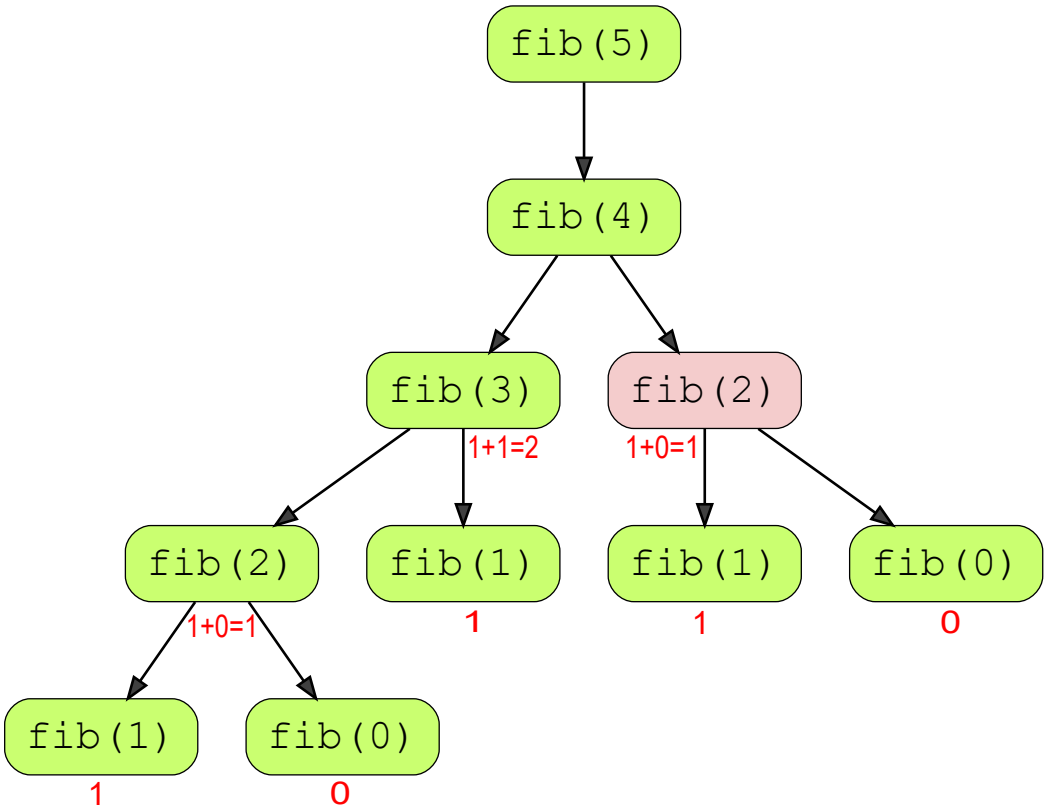

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
fib(2)
fib(1)
fib(1)
1
1
1+0=1
fib(1)
fib(0)
1
0

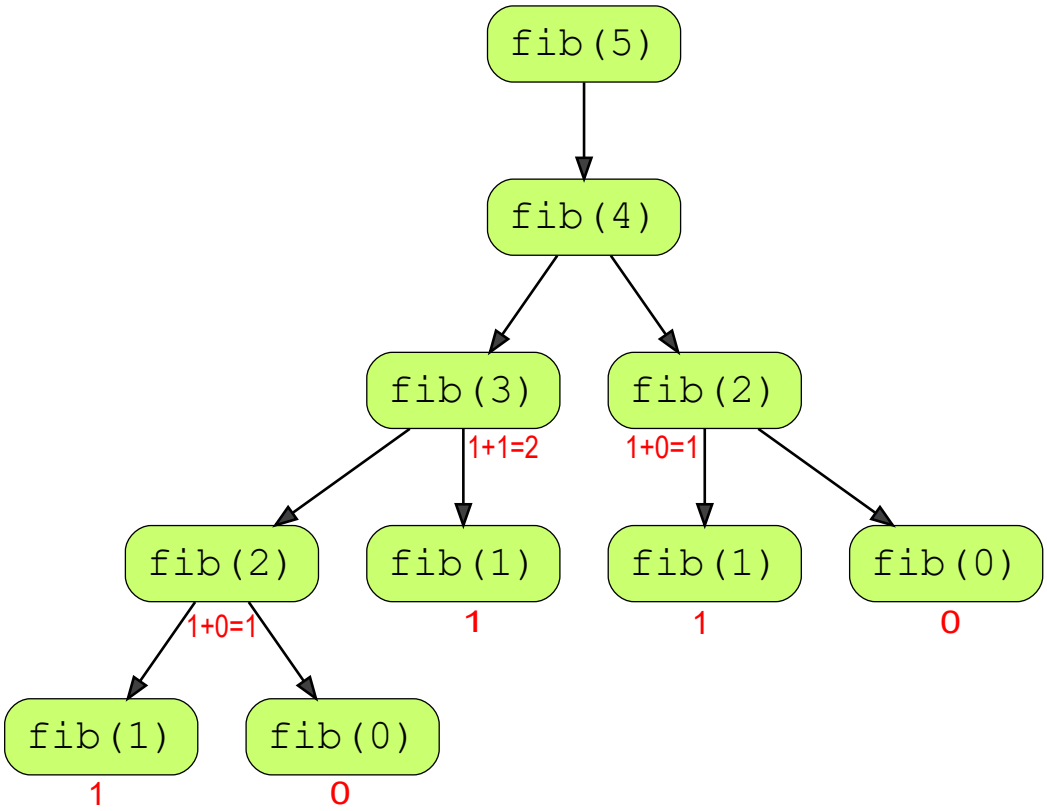

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
fib(2)
fib(1)
fib(1)
fib(0)
1+0=1
1
1
fib(1)
fib(0)
1
0

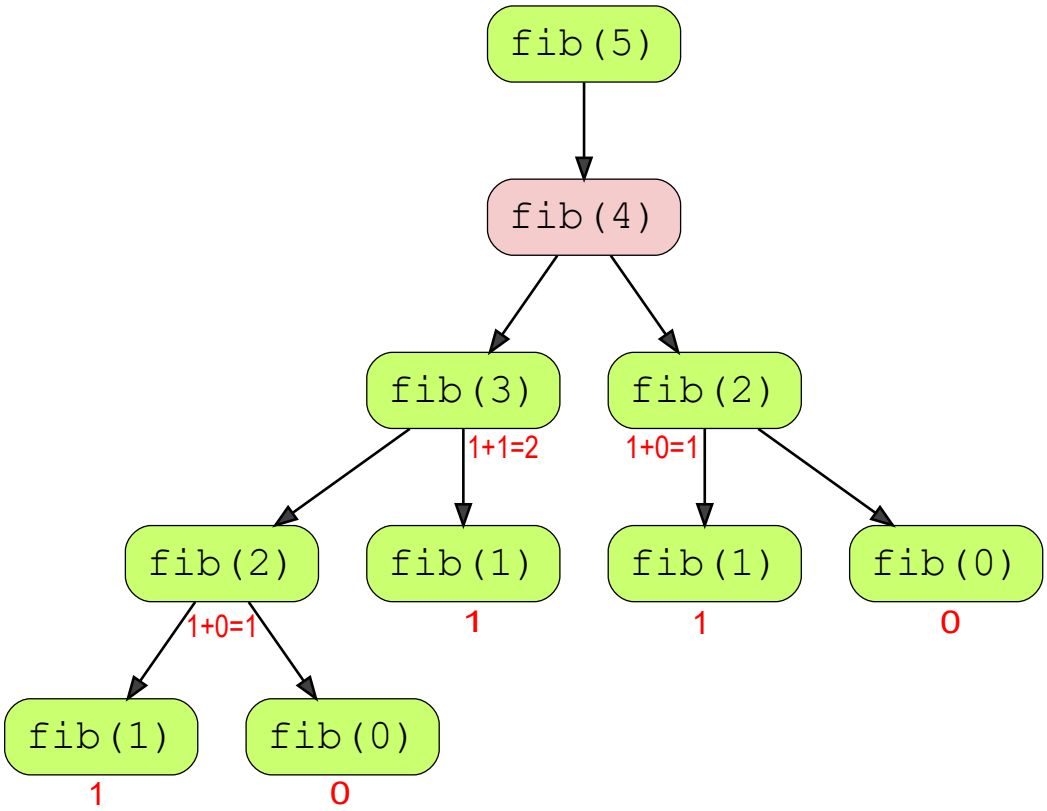

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
fib(2)
fib(1)
fib(1)
fib(0)
1+0=1
1
1
fib(1)
fib(0)
1
0

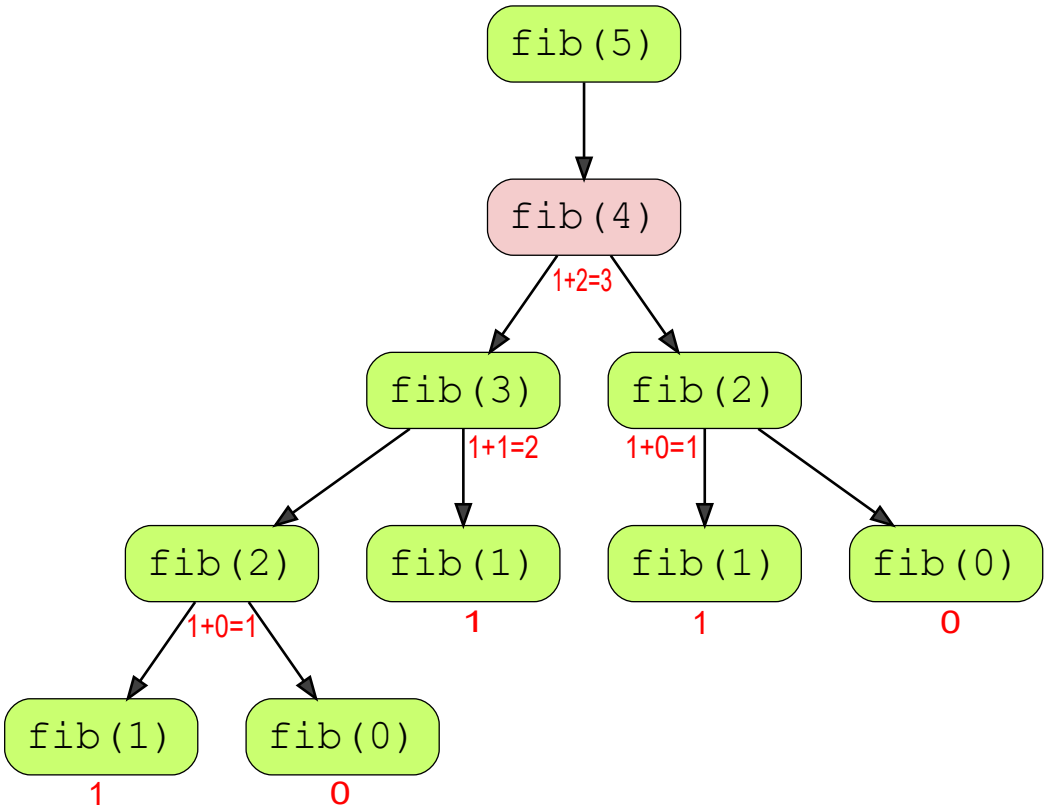

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
fib(2)
fib(1)
fib(1)
fib(0)
1+0=1
1
1
0
fib(1)
fib(0)
1
0

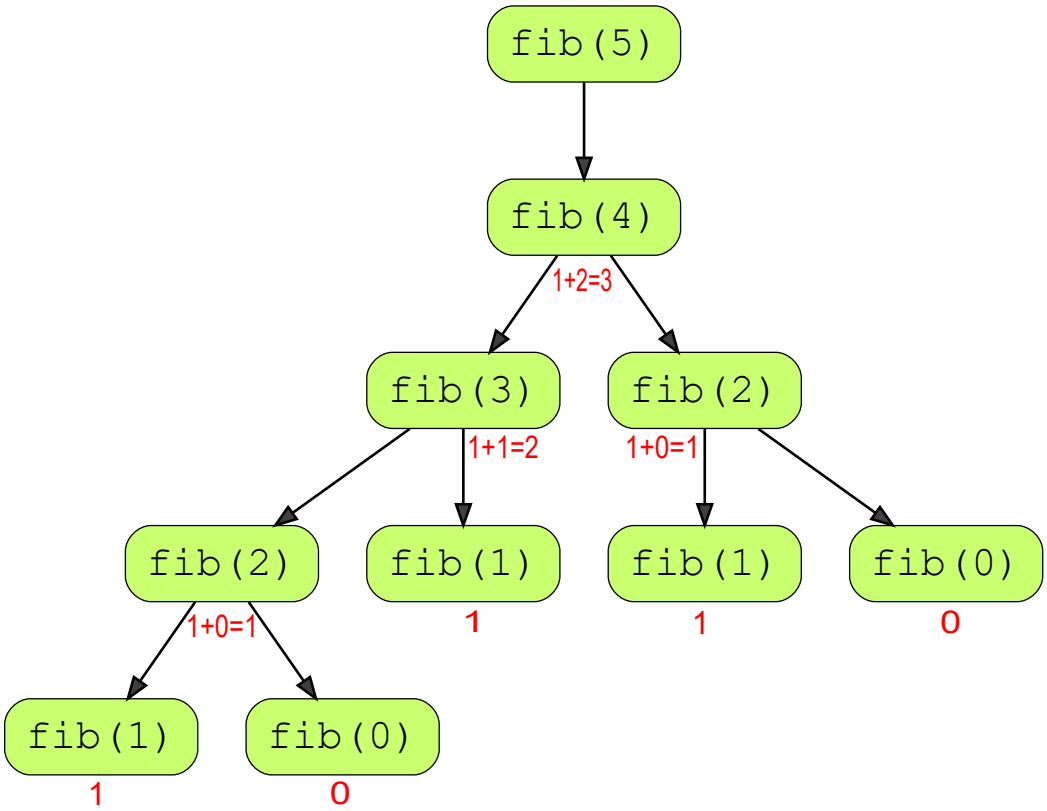

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
fib(2)
fib(1)
fib(1)
fib(0)
1+0=1
1
1
0
fib(1)
fib(0)
1
0

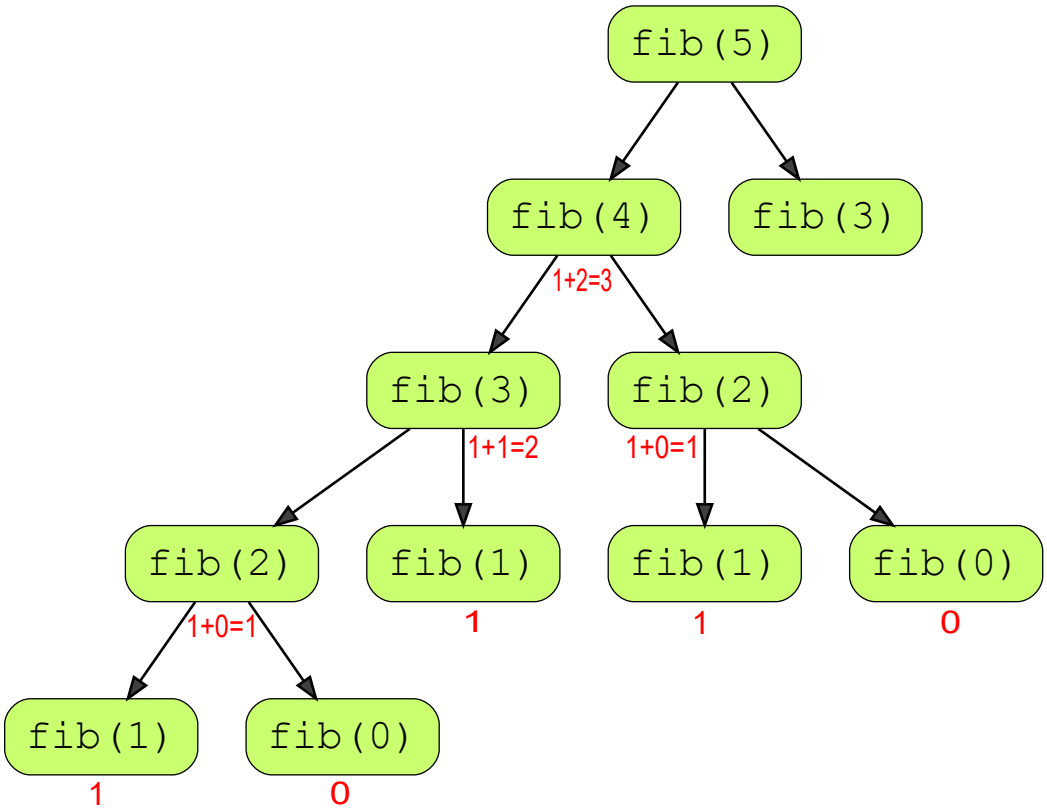

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1+0=1
1
1
0
fib(1)
fib(0)
1
0

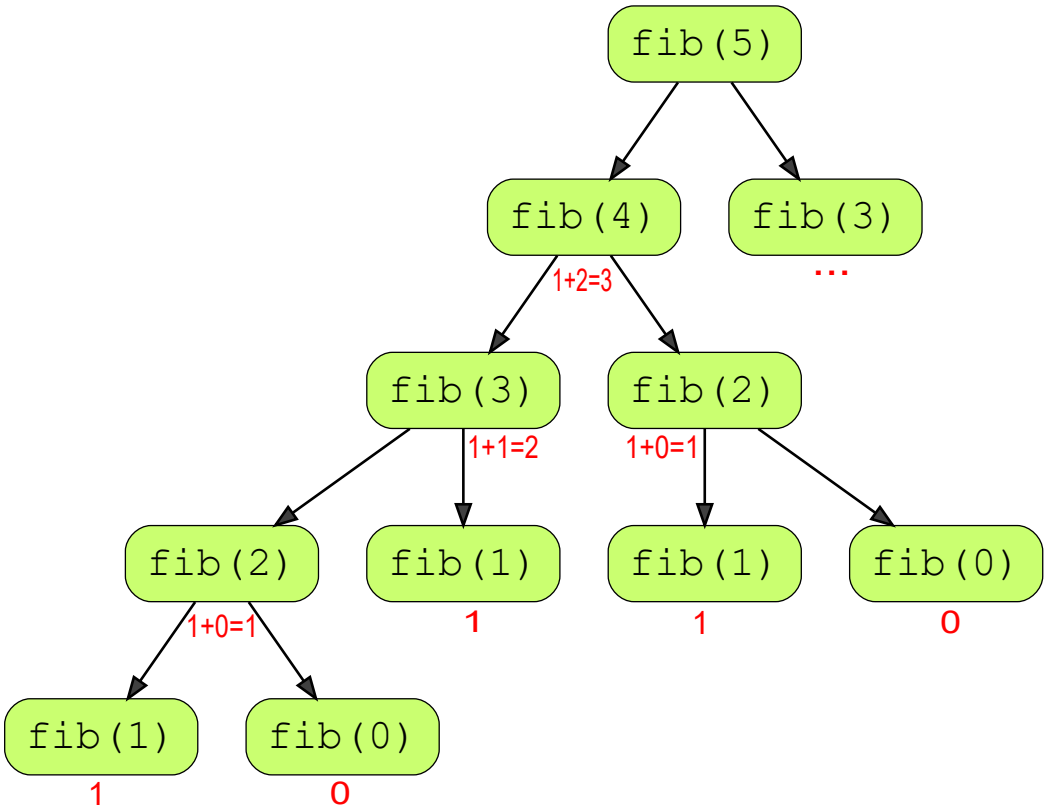

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1+0=1
1
1
0
fib(1)
fib(0)
1
0

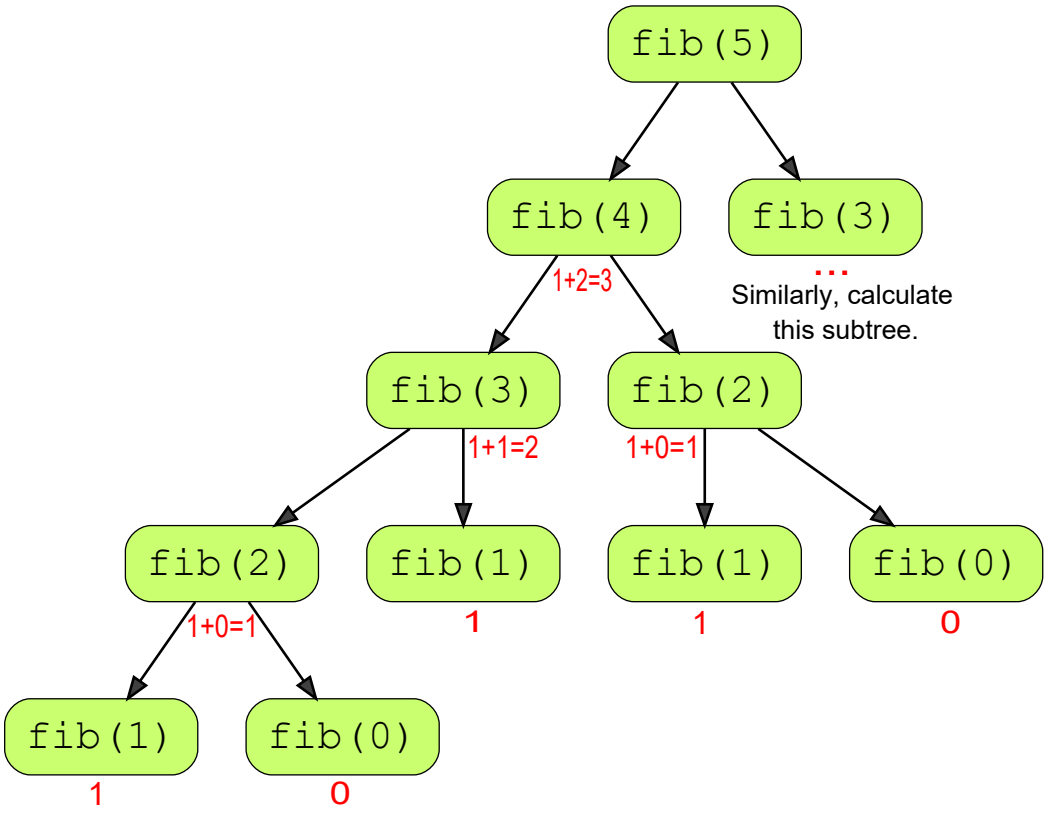

fib(5)
fib(4)
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1+0=1
1
1
0
fib(1)
fib(0)
1
0

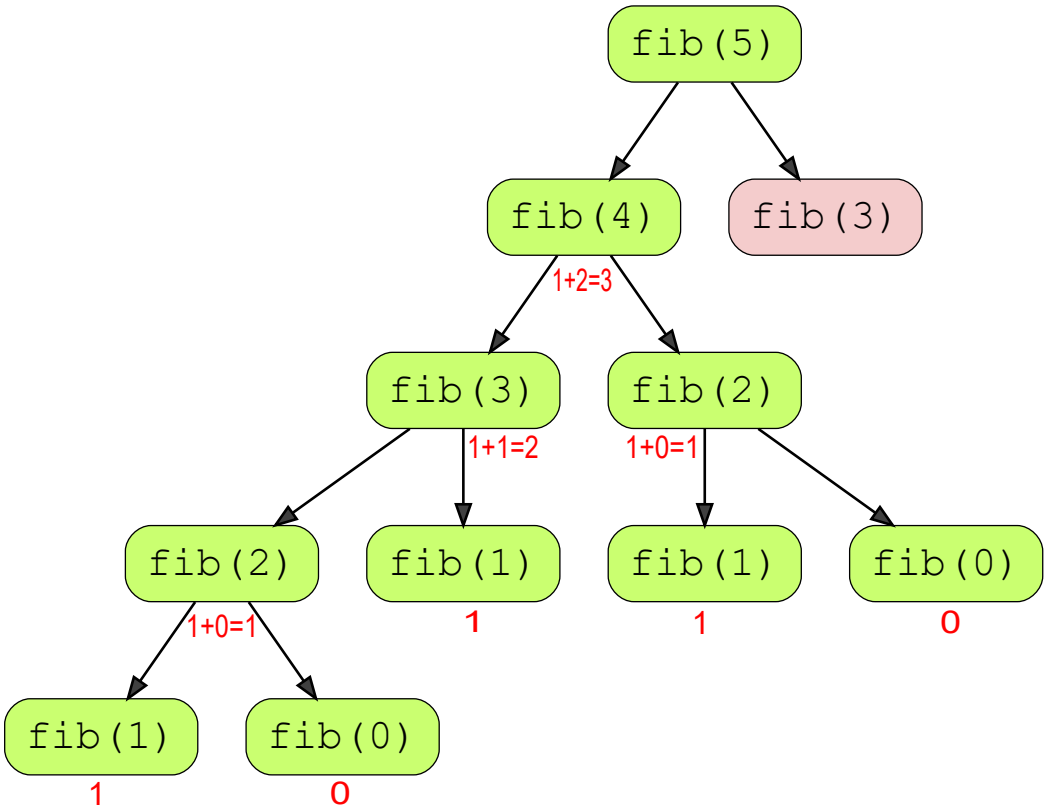

fib(5)
fib(4)
1+2=3
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1
1
0
1+0=1
fib(1)
fib(0)
1
0

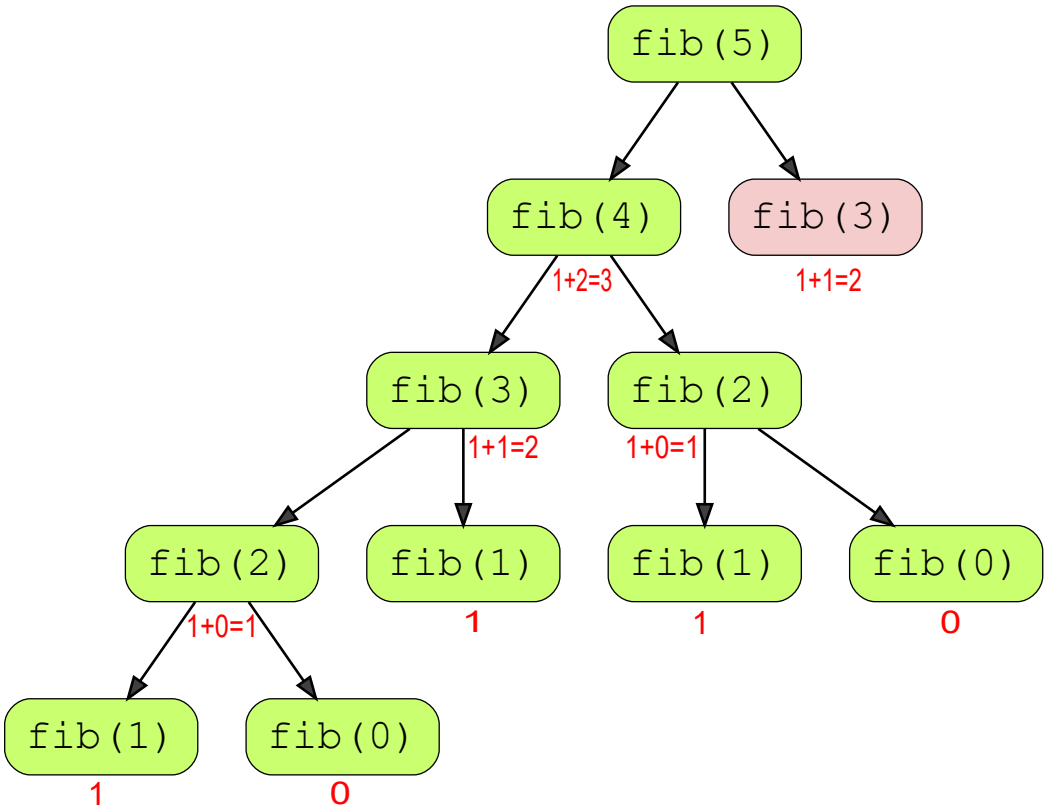

fib(5)
fib(4)
1+2=3
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1
1
0
1+0=1
fib(1)
fib(0)
1
0

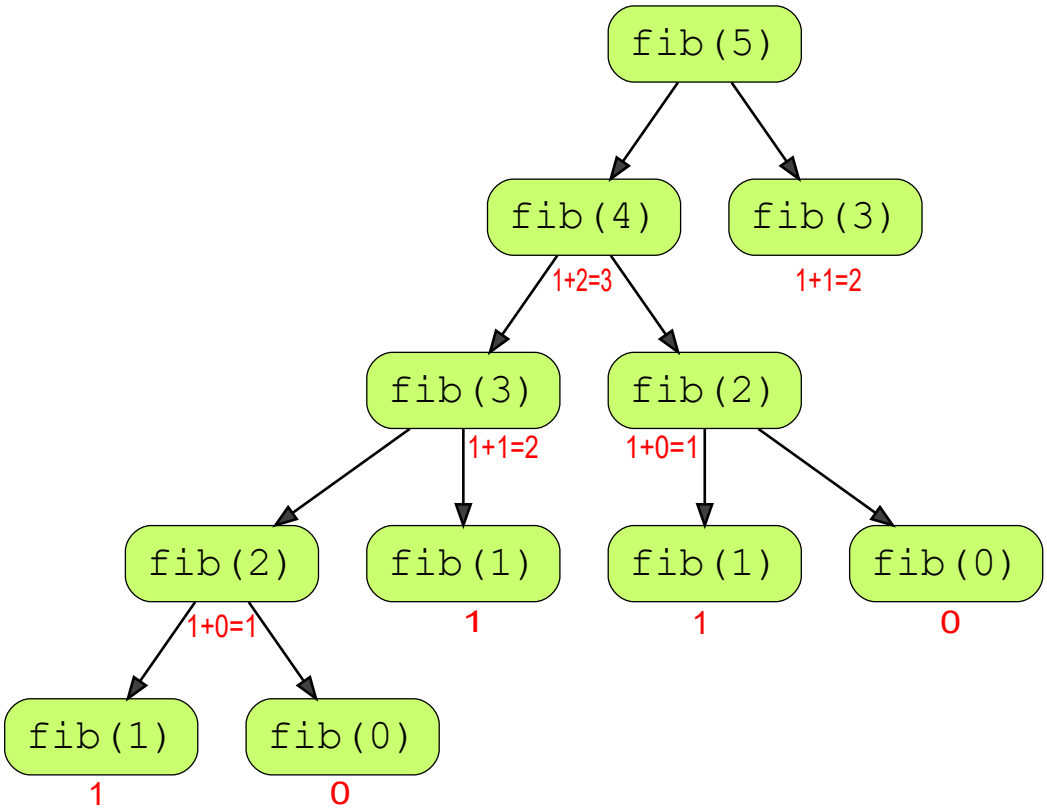

fib(5)
fib(4)
fib(3)
1+2=3
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1
1
0
1+0=1
fib(1)
fib(0)
1
0

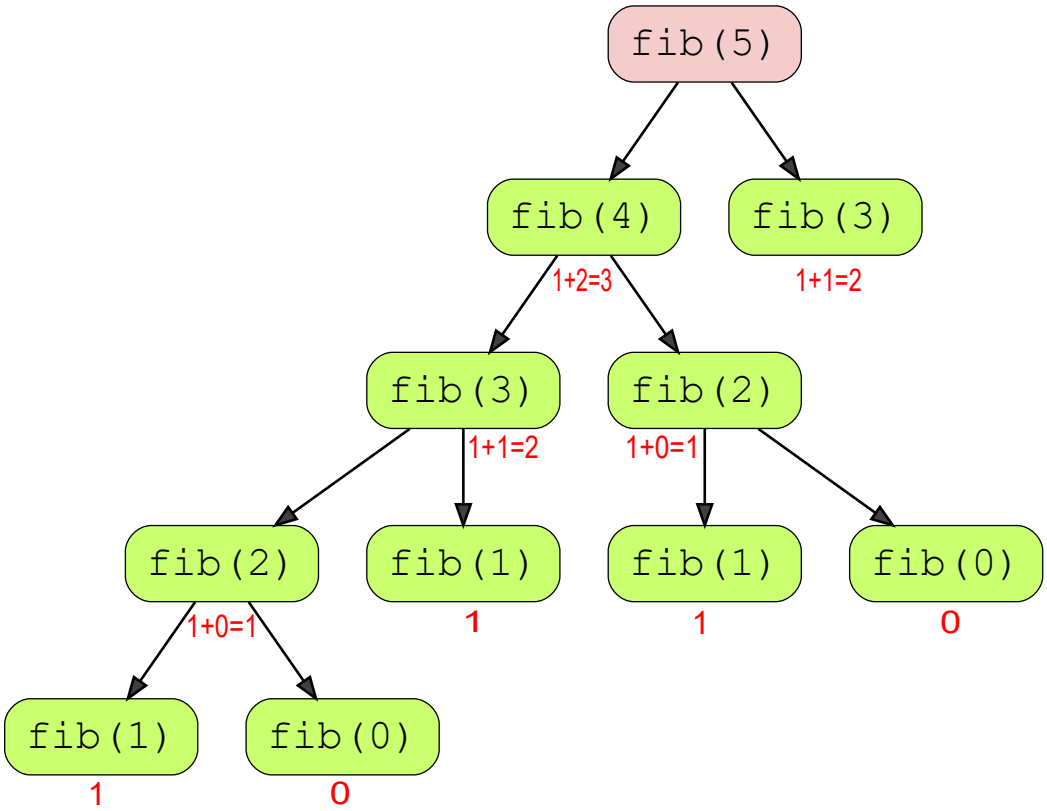

fib(5)
fib(4)
fib(3)
...
1+2=3
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1
1
0
1+0=1
fib(1)
fib(0)
1
0

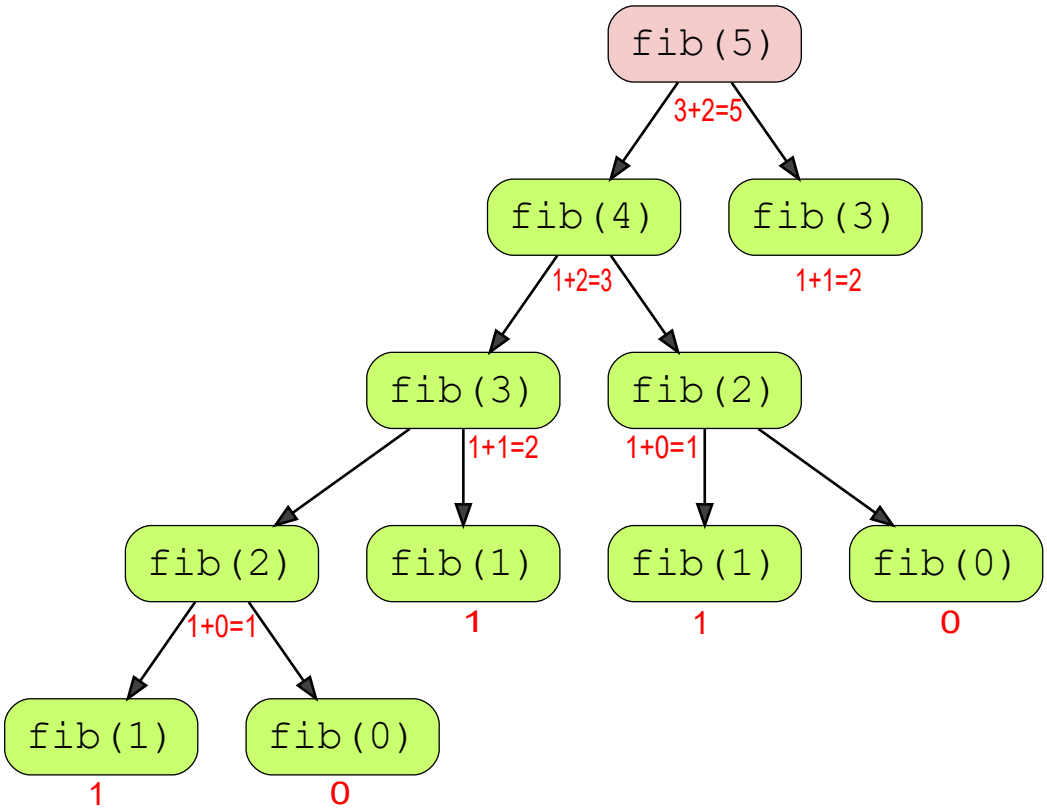

fib(5)
fib(4)
fib(3)
...
Similarly, calculate this subtree.
1+2=3
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1
1
0
1+0=1
fib(1)
fib(0)
1
0

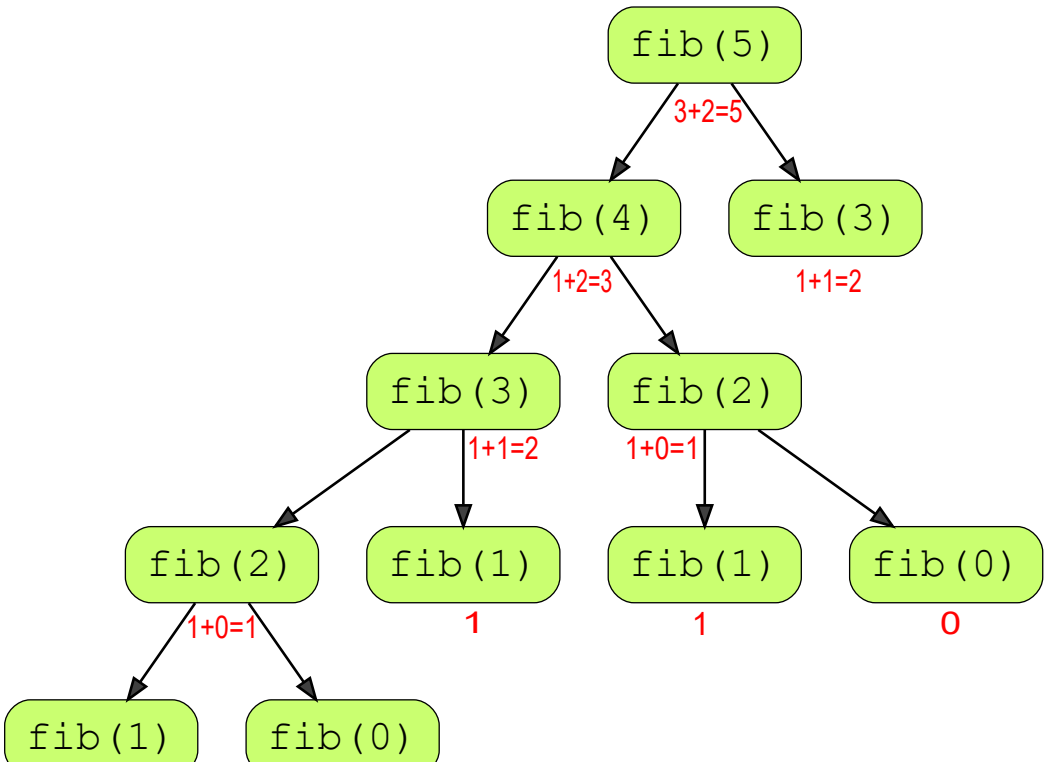

fib(5)
fib(4)
fib(3)
1+2=3
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1
1
0
1+0=1
fib(1)
fib(0)
1
0


fib(5)
fib(4)
fib(3)
1+1=2
1+2=3
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1
1
0
1+0=1
fib(1)
fib(0)
1
0


fib(5)
fib(4)
fib(3)
1+2=3
1+1=2
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1+0=1
1
1
0
fib(1)
fib(0)
1
0


fib(5)
fib(4)
fib(3)
1+2=3
1+1=2
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1+0=1
1
1
0
fib(1)
fib(0)
1
0


fib(5)
3+2=5
fib(4)
fib(3)
1+2=3
1+1=2
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1
1
0
1+0=1
fib(1)
fib(0)
1
0


fib(5)
3+2=5
fib(4)
fib(3)
1+2=3
1+1=2
fib(3)
fib(2)
1+1=2
1+0=1
fib(2)
fib(1)
fib(1)
fib(0)
1
1
0
1+0=1
fib(1)
fib(0)

Notice that none of these have any clue that they are actually a part of a bigger process to calculate `fib(5)`. For instance, no `fib(1)` knows that it will be added to `fib(0)` and be used to calculate `fib(5)` at the end.

How do we know that `fib(3)` has to be added to `fib(2)` to make `fib(4)`, or `fib(2)` has to be added to `fib(1)` to make `fib(3)`? Where do we keep this information? All this information is in the call stack.

If at any point during the process, we were to pause and continue the process in a new environment with a clean stack, we would be unable to calculate `fib(5)` because the call stack has been wiped clean.

> Think of a recursive process as a series of deferred operations, where there is information hidden to each recursive call - that hidden information is in the call stack.

Notice, that in the above code some functions, `fib(0)` and `fib(1)` for instance, are called multiple times. There is no memory of them ever being called before. As a result, the memory complexity is **O(n)**. If we run this program for large numbers, it throws an error.

```
function sumToN( n, sum = 0 ) {
    if ( n <= 1 ) return sum;
    let result = sum + n;
    return sumToN( n - 1, result );
};

console.time( 'recursion' );
console.log( sumToN( 1000000 ) ); //the code works if you replace 1000000 with a smaller numb
console.timeEnd( 'recursion' );
```

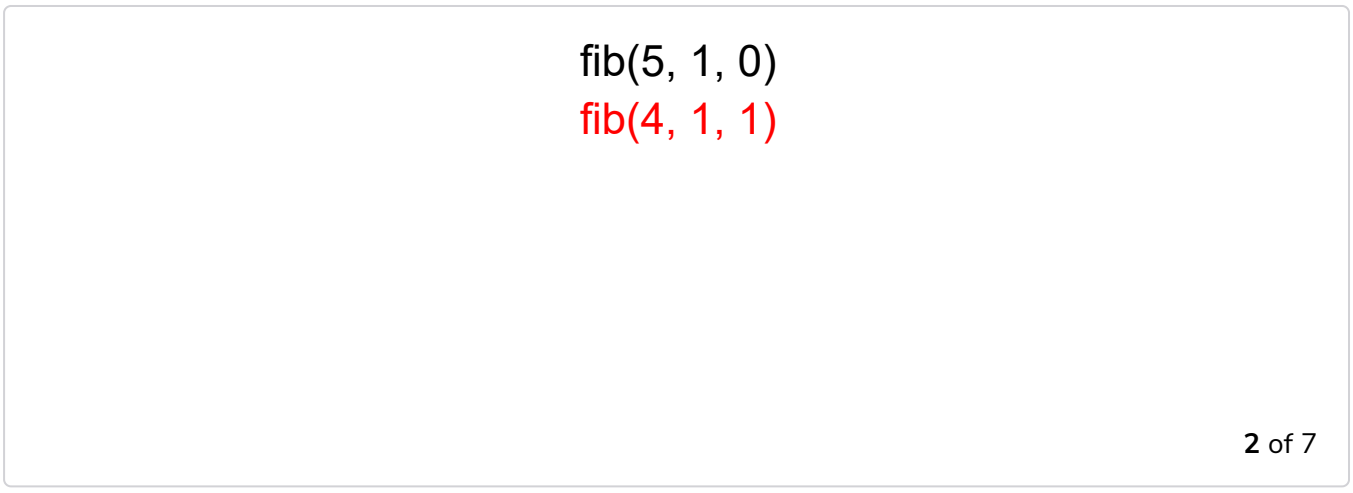
RangeError: Maximum call stack size exceeded

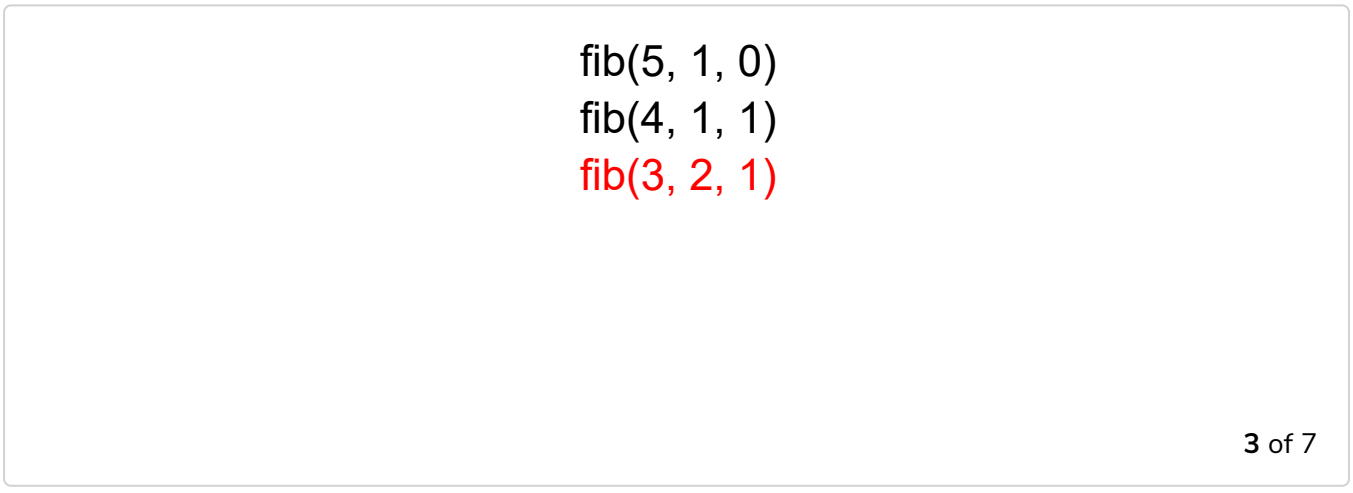
Now, we will write the same function using tail call optimization:

Now, we will write the same function using tail call optimization:

```
function fib(n, a, b){
  if (n === 0) {
    return b;
  } else {
    return fib(n-1, a + b, a);
  }
};
```

When we run this function, here is what the function calls will look like:





fib(5, 1, 0)
fib(4, 1, 1)
fib(3, 2, 1)
fib(2, 3, 2)

fib(5, 1, 0)
fib(4, 1, 1)
fib(3, 2, 1)
fib(2, 3, 2)
fib(1, 5, 3)

fib(5, 1, 0)
fib(4, 1, 1)
fib(3, 2, 1)
fib(2, 3, 2)
fib(1, 5, 3)
fib(0, 8, 5)

fib(5, 1, 0)
fib(4, 1, 1)
fib(3, 2, 1)
fib(2, 3, 2)
fib(1, 5, 3)
fib(0, 8, 5)

In this implementation, the entire state of the process is encapsulated in each function call. If we were to pause the process midway and start with a clean stack, we would still get the correct output. Moreover, the memory complexity is **O(1)**.

The current support for tail call optimization is currently very low. It will take time until you will be able to benefit from properly optimized tail calls. See the current compatibility table.

On Google Chrome, the feature status can be seen here. Currently, Safari is the only main browser that supports tail calls.

Once browser support is better, I will rewrite this section. Until then, know that tail call optimization exists.

We will now move on to the name property in ES6.