Interview Cake

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Bottom-Up Algorithms

Going **bottom-up** is a way to avoid recursion, saving the **memory cost** that recursion incurs when it builds up the **call stack**.

Put simply, a bottom-up algorithm "starts from the beginning," while a recursive algorithm often "starts from the end and works backwards."

For example, if we wanted to multiply all the numbers in the range $1..n$, we could use this cute, **top-down**, recursive one-liner:

Python 2.7

```
def product_1_to_n(n):
    # We assume n >= 1
    return n * product_1_to_n(n - 1) if n > 1 else 1
```

This approach has a problem: it builds up a **call stack** of size $O(n)$, which makes our total memory cost $O(n)$. This makes it vulnerable to a **stack overflow error**, where the call stack gets too big and runs out of space.

To avoid this, we can instead go **bottom-up**:

Python 2.7 ▾

```
def product_1_to_n(n):
    # We assume n >= 1
    result = 1
    for num in range(1, n + 1):
        result *= num

    return result
```

This approach uses $O(1)$ space ($O(n)$ time).

> *Some* compilers and interpreters will do what's called **tail call optimization** (TCO), where it can optimize *some* recursive functions to avoid building up a tall call stack. Python and Java decidedly do not use TCO. Some Ruby implementations do, but most don't. Some C implementations do, and the JavaScript spec recently *allowed* TCO. Scheme is one of the few languages that *guarantee* TCO in all implementations. In general, best not to assume your compiler/interpreter will do this work for you.

Going bottom-up is a common strategy for **dynamic programming** problems, which are problems where the solution is composed of solutions to the same problem with smaller inputs (as with multiplying the numbers $1..n$, above). The other common strategy for dynamic programming problems is **memoization (/concept/memoization)**.

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Next up: Recursive String Permutations ➡ (/question/recursive-string-permutations?course=fc1&section=dynamic-programming-recursion)

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