Recursion I

Overview

```
/*
   - Definition of recursion
   - The call stack
   - countdown example
   - factorial example
   - Recursion and arrays, strings
   - Tips for approaching recursion problems
*/
```

Definition

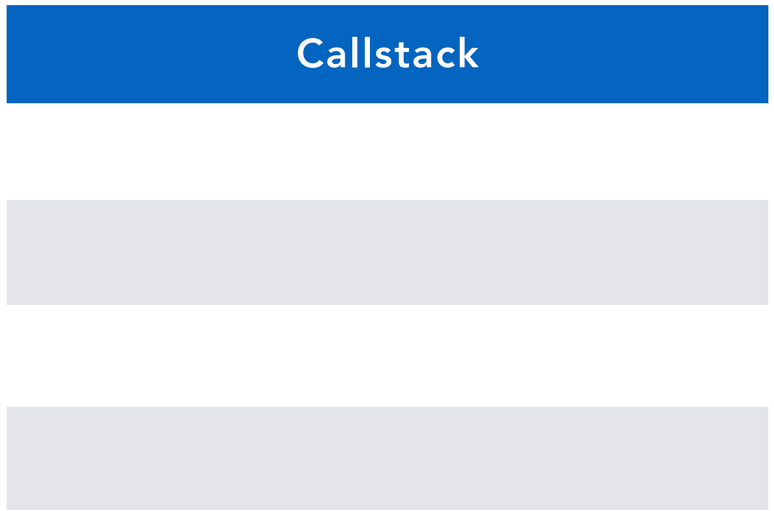
```
/* recursion occurs when a function calls itself!  */

/* recursion is an alternative to iteration (using a loop) */

/* in the real world, you may see recursion instead of iteration when a
   recursive solution is:
     - easier to reason about (recursion helps break big problems into
       small chunks
     - easier to read than an iterative solution
     - won't negatively affect performance too much (recursion can be
       a memory hog) */
```

The call stack

```
1   /* before we talk about recursion, we have to talk about the call stack */
2
3   /* JS is "single threaded" - can only run one function at a time */
4
5   /* the call stack is the structure JS uses to figure out which function
6      it should be running at any point in time */
7
8
9
10
11
12
13
14
```

The call stack

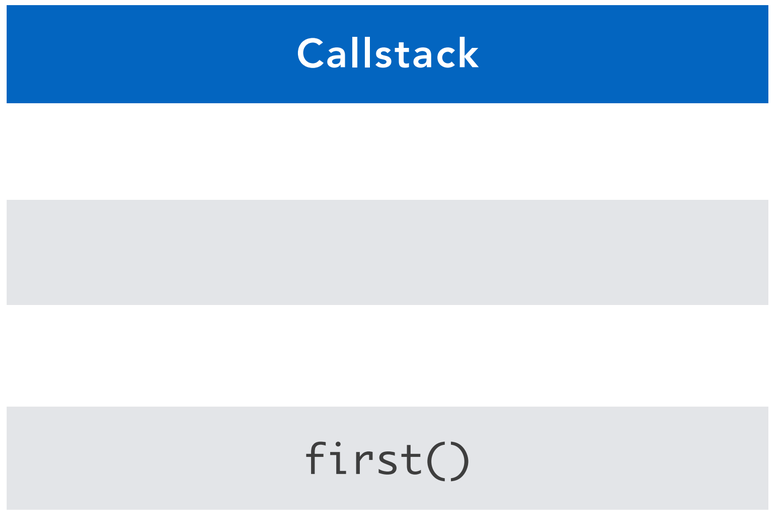
```
1  /* whenever we call a function, it's added to the top of the call stack */
2
3  /* JS will execute whatever function is on the top of the stack */
4
5  function first() {
6    console.log('I am first!');
7  }
8
9  function second() {
10   console.log('I am second!');
11 }
12
13 first();
14 second();
```



I am first

The call stack

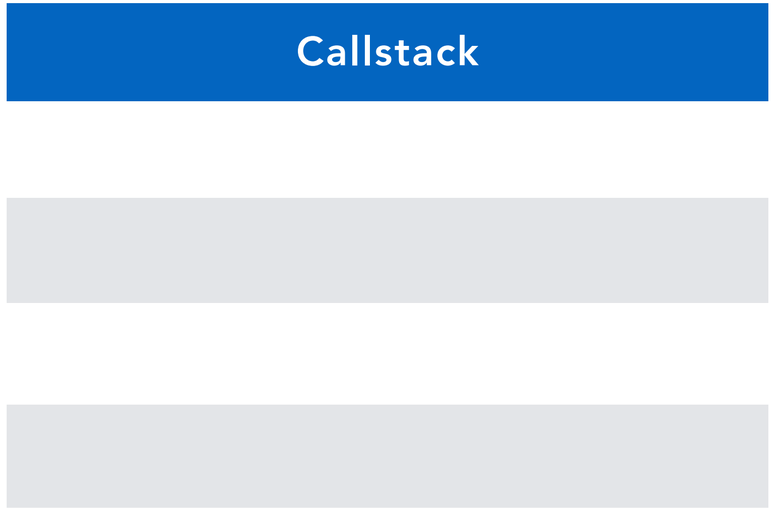
```
1  /* whenever we call a function, it's added to the top of the call stack */
2
3  /* JS will execute whatever function is on the top of the stack */
4
5  function first() {
6    console.log('I am first!');
7  }
8
9  function second() {
10   console.log('I am second!');
11 }
12
13 first();
14 second();
```



I am first

The call stack

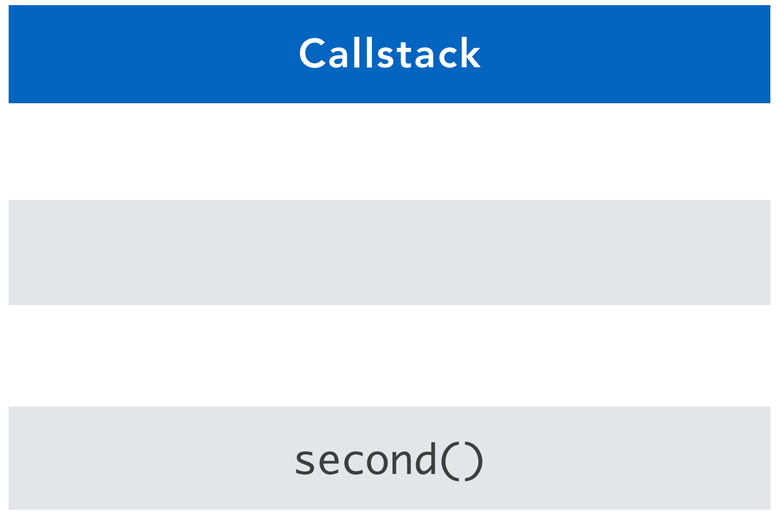
```
1  /* whenever we call a function, it's added to the top of the call stack */
2
3  /* JS will execute whatever function is on the top of the stack */
4
5  function first() {
6    console.log('I am first!');
7  }
8
9  function second() {
10   console.log('I am second!');
11 }
12
13 first();
14 second();
```



```
I am first
I am second
```

The call stack

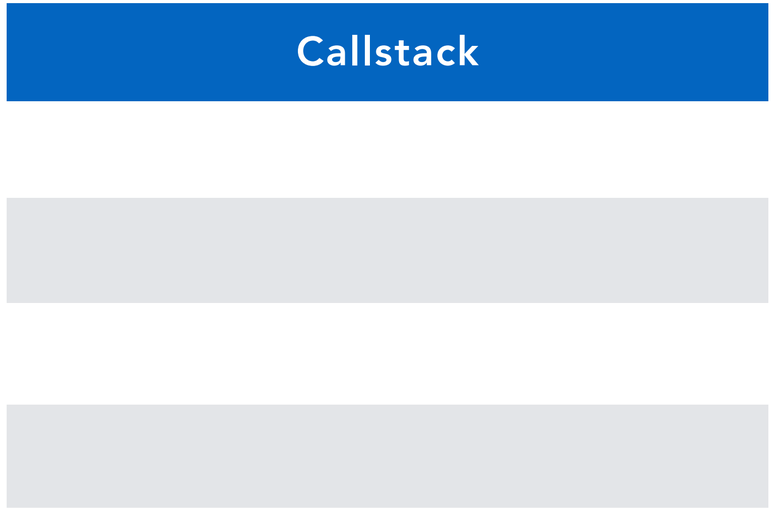
```
1  /* whenever we call a function, it's added to the top of the call stack */
2
3  /* JS will execute whatever function is on the top of the stack */
4
5  function first() {
6    console.log('I am first!');
7  }
8
9  function second() {
10   console.log('I am second!');
11 }
12
13 first();
14 second();
```



```
I am first
I am second
```

The call stack

```
1  /* whenever we call a function, it's added to the top of the call stack */
2
3  /* JS will execute whatever function is on the top of the stack */
4
5  function first() {
6    console.log('I am first!');
7  }
8
9  function second() {
10   console.log('I am second!');
11 }
12
13 first();
14 second();
```



The call stack

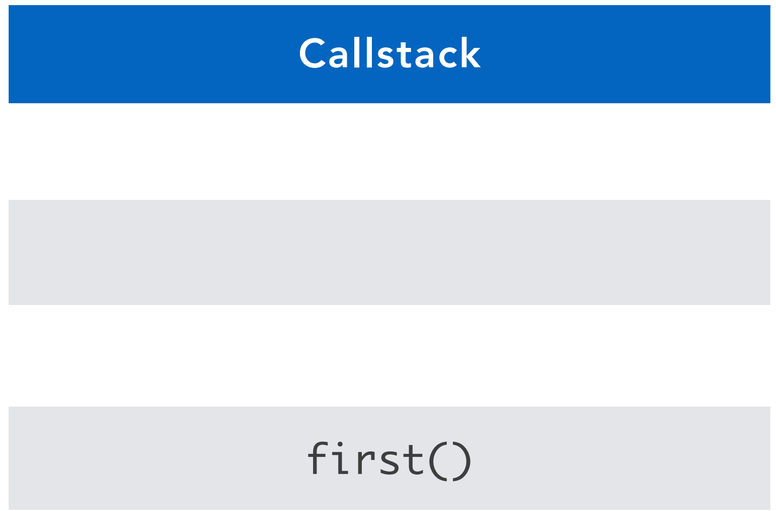
```
1   function first() {
2     console.log('I am first!');
3     second();
4     console.log('First is finished');
5   }
6
7   function second() {
8     console.log('I am second!');
9   }
10
11  first();
12
13
14
```

Callstack

I am first

The call stack

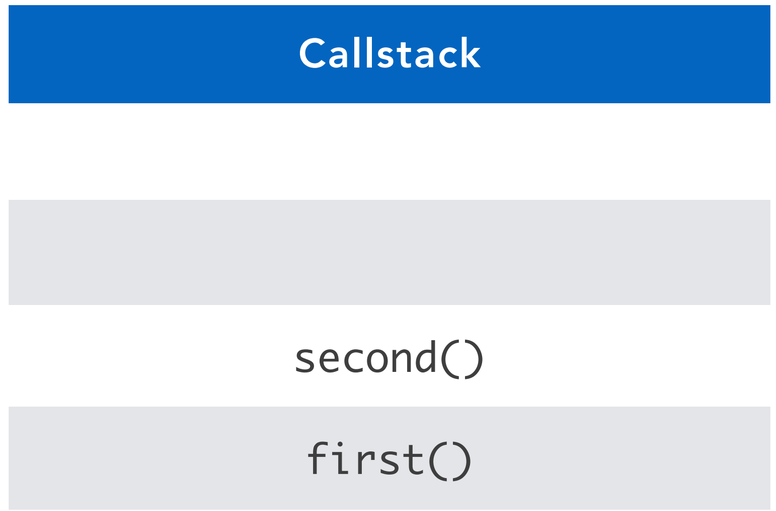
```
1   function first() {
2     console.log('I am first!');
3     second();
4     console.log('First is finished');
5   }
6
7   function second() {
8     console.log('I am second!');
9   }
10
11  first();
12
13
14
```



The call stack

```
I am first
I am second
```

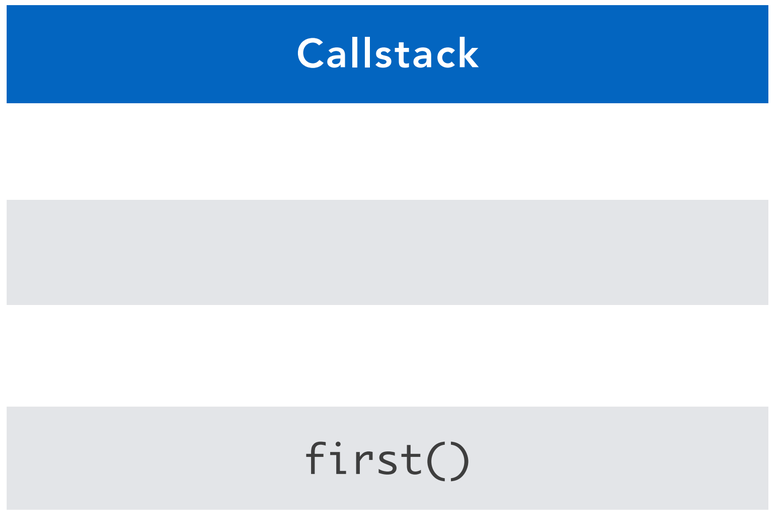
```
1   function first() {
2     console.log('I am first!');
3     second();
4     console.log('First is finished');
5   }
6
7   function second() {
8     console.log('I am second!');
9   }
10
11  first();
12
13
14
```



The call stack

```
I am first
I am second
First is finished
```

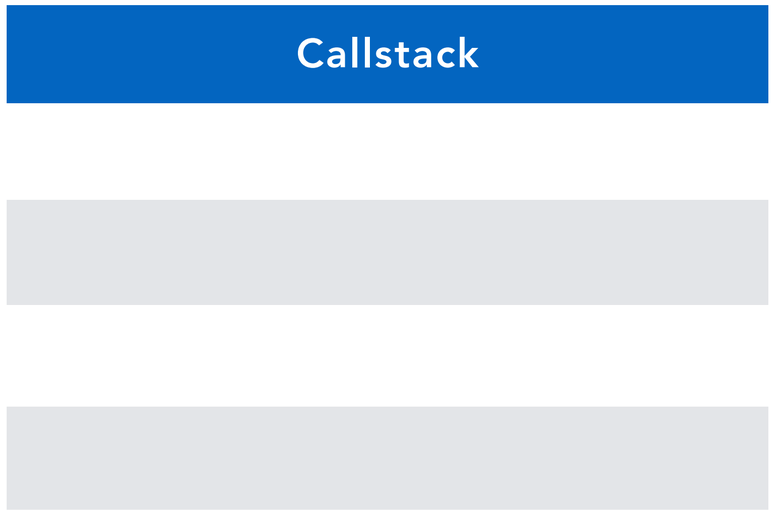
```
1   function first() {
2     console.log('I am first!');
3     second();
4     console.log('First is finished'); // first "paused" while second ran
5   }
6
7   function second() {
8     console.log('I am second!');
9   }
10
11  first();
12
13
14
```



The call stack

```
I am first
I am second
First is finished
```

```
1   function first() {
2     console.log('I am first!');
3     second();
4     console.log('First is finished'); // first "paused" while second ran
5   }
6
7   function second() {
8     console.log('I am second!');
9   }
10
11  first();
12
13
14
```



example: countdown

```
5
4
3
2
1
```

```
/* write a function that counts down to 1 */

function countdown(num) {
  for (let i = num; i >= 1; i--) {
    console.log(i);
  }
}

countdown(5);
```

example: countdown

```
5
4
3
2
1
```

```
/* let's refactor our solution, writing a function that takes a number and
   and logs it out */

function countdown(num) {
  console.log(num);
}

countdown(5);
countdown(4);
countdown(3);
countdown(2); // notice, no loops!
countdown(1); // how do the arguments change between calls?


```

example: countdown

```
1  /* every time we called countdown, we subtracted one from the previous
2     num */
3
4  /* instead of manually calling countdown over and over, why not have
5     countdown call itself, subtracting one from num each time? */
6
7  function countdown(num) {
8    console.log(num);
9    countdown(num - 1);
10 }
11
12 countdown(5);
13
14
```

Callstack

example: countdown

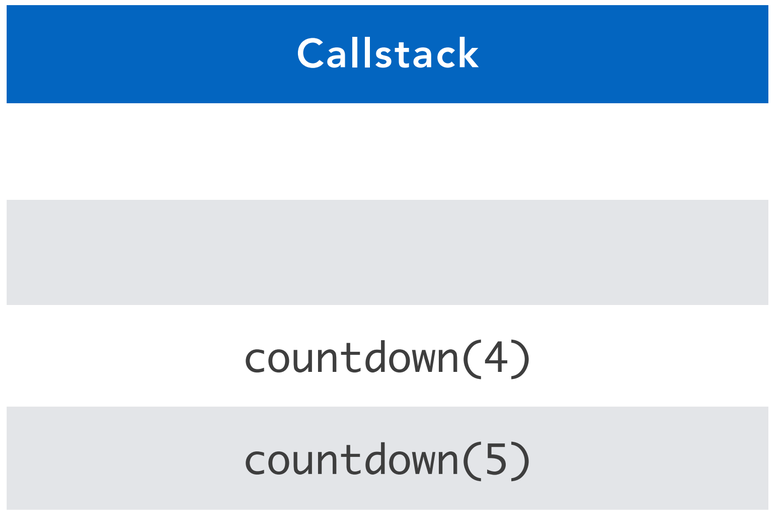
```
1  /* every time we called countdown, we subtracted one from the previous
2     num */
3
4  /* instead of manually calling countdown over and over, why not have
5     countdown call itself, subtracting one from num each time? */
6
7  function countdown(num) {
8    console.log(num);
9    countdown(num - 1);
10 }
11
12 countdown(5);
13
14
```

Callstack

countdown(5)

example: countdown

```
1  /* every time we called countdown, we subtracted one from the previous
2     num */
3
4  /* instead of manually calling countdown over and over, why not have
5     countdown call itself, subtracting one from num each time? */
6
7  function countdown(num) {
8    console.log(num);
9    countdown(num - 1);
10 }
11
12 countdown(5);
13
14
```



example: countdown

5
4
3

```
1   /* every time we called countdown, we subtracted one from the previous
2      num */
3
4   /* instead of manually calling countdown over and over, why not have
5      countdown call itself, subtracting one from num each time? */
6
7   function countdown(num) {
8     console.log(num);
9     countdown(num - 1);
10  }
11
12  countdown(5);
13
14
```

Callstack

countdown(3)

countdown(4)

countdown(5)

example: countdown

```
5
4
3
2
```

```
1  /* every time we called countdown, we subtracted one from the previous
2     num */
3
4  /* instead of manually calling countdown over and over, why not have
5     countdown call itself, subtracting one from num each time? */
6
7  function countdown(num) {
8    console.log(num);
9    countdown(num - 1);
10 }
11
12 countdown(5);
13
14
```

Callstack
countdown(2)
countdown(3)
countdown(4)
countdown(5)

example: countdown

```
5
4
3
2
1
```

```
/* every time we called countdown, we subtracted one from the previous
   num */

/* instead of manually calling countdown over and over, why not have
   countdown call itself, subtracting one from num each time? */

function countdown(num) {
  console.log(num);
  countdown(num - 1);
}

countdown(5);

```

Callstack
countdown(1)
countdown(2)
countdown(3)
countdown(4)
countdown(5)

example: countdown

```
5
4
3
2
1
0
```

```
/* every time we called countdown, we subtracted one from the pr
   num */

/* instead of manually calling countdown over and over, why not have
   countdown call itself, subtracting one from num each time? */

function countdown(num) {
  console.log(num);
  countdown(num - 1);
}

countdown(5);
```

Callstack
countdown(0)
countdown(1)
countdown(2)
countdown(3)
countdown(4)
countdown(5)

example: countdown

```
5
4
3
2
1
0
-1
```

```
/* every time we called countdown, we subtracted one from the pr
   num */

/* instead of manually calling countdown over and over, why not have
   countdown call itself, subtracting one from num each time? */

function countdown(num) {
  console.log(num);
  countdown(num - 1);
}

countdown(5);
```

Callstack
countdown(-1)
countdown(0)
countdown(1)
countdown(2)
countdown(3)
countdown(4)
countdown(5)

example: countdown

```
5
4
3
2
1
0
-1
-2
```

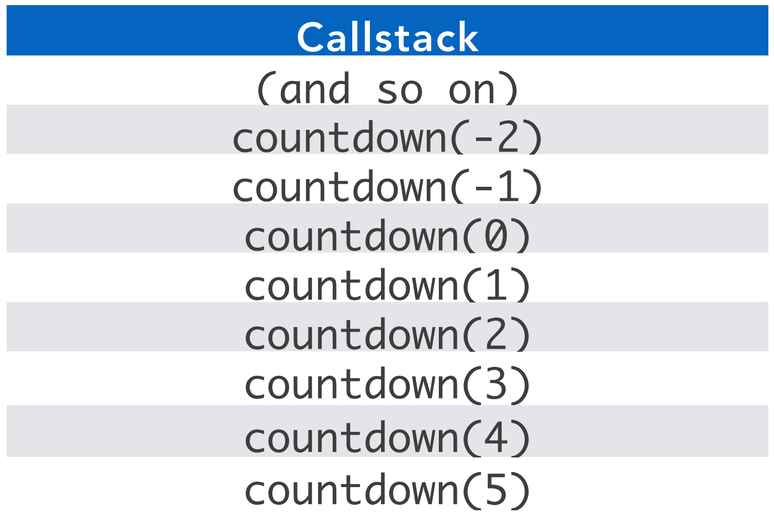
```
/* every time we called countdown, we subtracted one from the pr
   num */

/* instead of manually calling countdown over and over, why not have
   countdown call itself, subtracting one from num each time? */

function countdown(num) {
  console.log(num);
  countdown(num - 1);
}

countdown(5);
```

Callstack
countdown(-2)
countdown(-1)
countdown(0)
countdown(1)
countdown(2)
countdown(3)
countdown(4)
countdown(5)

example: countdown

```
5
4
3
2
1
0
-1
-2
(and so on)
```

```
1  /* every time we called countdown, we subtracted one from the pr
2     num */
3
4  /* instead of manually calling countdown over and over, why not have
5     countdown call itself, subtracting one from num each time? */
6
7  function countdown(num) {
8    console.log(num);
9    countdown(num - 1);
10 }
11
12 countdown(5);
13
14
```



example: countdown

```
1  /* every time we called countdown, we subtracted one from the pr
2     num */
3
4  /* instead of manually calling countdown over and over, why not
5     countdown call itself, subtracting one from num each time? */
6
7  function countdown(num) {
8    console.log(num);
9    countdown(num - 1);
10 }
11
12 countdown(5);
13
14
```

```
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
RangeError:
Maximum call
stack size
exceeded
```

example: countdown

```
1   /* that started off so promisingly! */
2
3   /* because our function was instructed to call itself every time, the
4      function ends up calling itself forever until our computer runs out of
5      memory */
6
7   /* let's write in a stop condition so the function eventually stops
8      calling itself */
9
10
11
12
13
14
```

example: countdown

```
1   function countdown(num) {
2     // here's our stop condition, commonly known as the 'base case'
3     if (num < 1) {
4       console.log('done!');
5     }
6     // here's our 'recursive case'
7     else {
8       console.log(num);
9       countdown(num - 1);
10    }
11  }
12
13  countdown(3);
14
```

Callstack

example: countdown

```
1   function countdown(num) {
2     // here's our stop condition, commonly known as the 'base case'
3     if (num < 1) {
4       console.log('done!');
5     }
6     // here's our 'recursive case'
7     else {
8       console.log(num);
9       countdown(num - 1);
10    }
11  }
12
13  countdown(3);
14
```

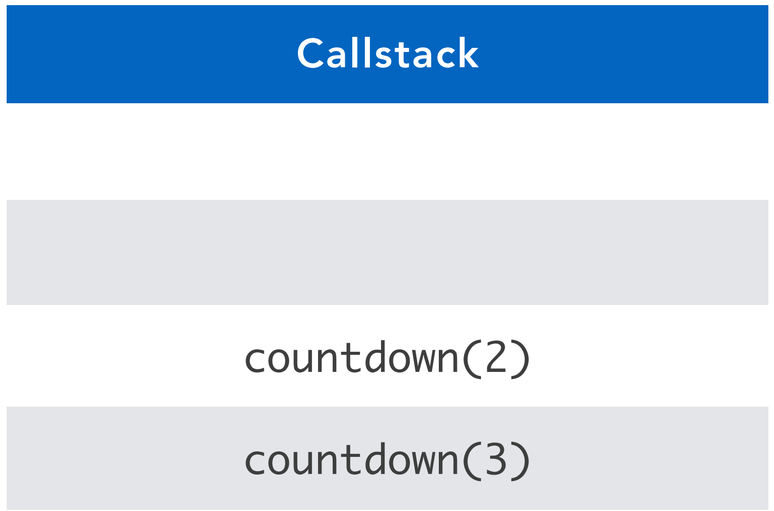
Callstack

countdown(3)

3
2

example: countdown

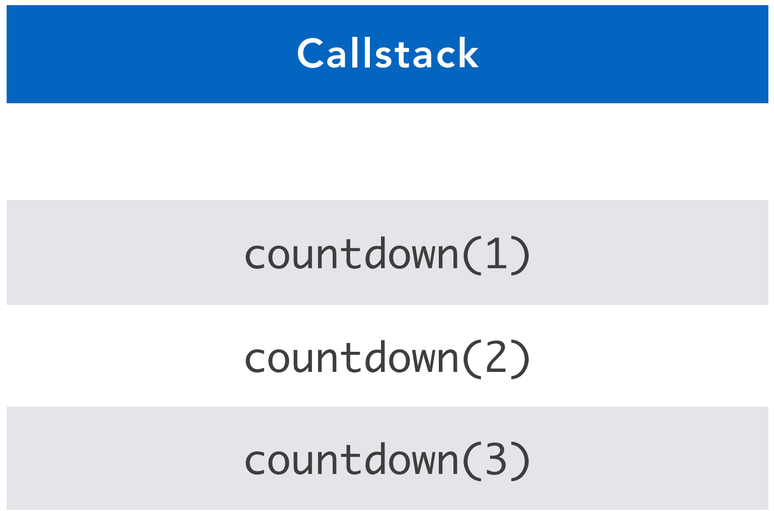
```
1   function countdown(num) {
2     // here's our stop condition, commonly known as the 'base case'
3     if (num < 1) {
4       console.log('done!');
5     }
6     // here's our 'recursive case'
7     else {
8       console.log(num);
9       countdown(num - 1);
10    }
11  }
12
13  countdown(3);
14
```



example: countdown

```
3
2
1
```

```
1   function countdown(num) {
2     // here's our stop condition, commonly known as the 'base case'
3     if (num < 1) {
4       console.log('done!');
5     }
6     // here's our 'recursive case'
7     else {
8       console.log(num);
9       countdown(num - 1);
10    }
11  }
12
13  countdown(3);
14
```



example: countdown

```
3
2
1
done!
```

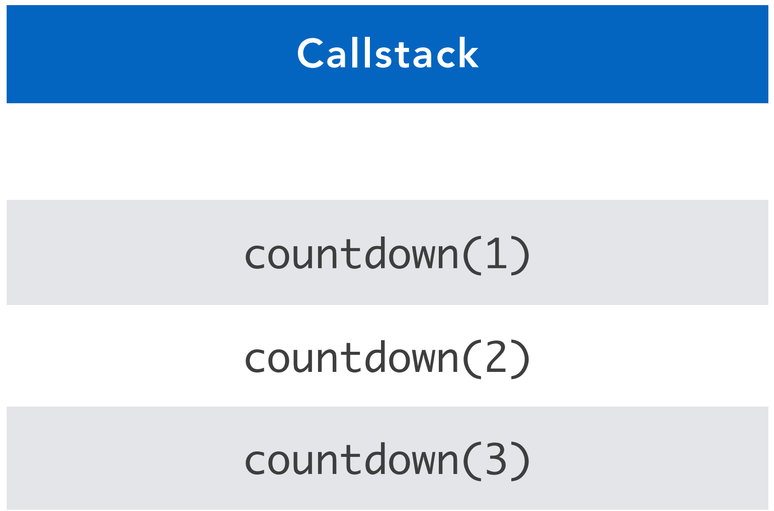
```
1   function countdown(num) {
2     // here's our stop condition, commonly known as the 'base case'
3     if (num < 1) {
4       console.log('done!');
5     }
6     // here's our 'recursive case'
7     else {
8       console.log(num);
9       countdown(num - 1);
10    }
11  }
12
13  countdown(3);
14
```

Callstack
countdown(0)
countdown(1)
countdown(2)
countdown(3)

example: countdown

```
3
2
1
done!
```

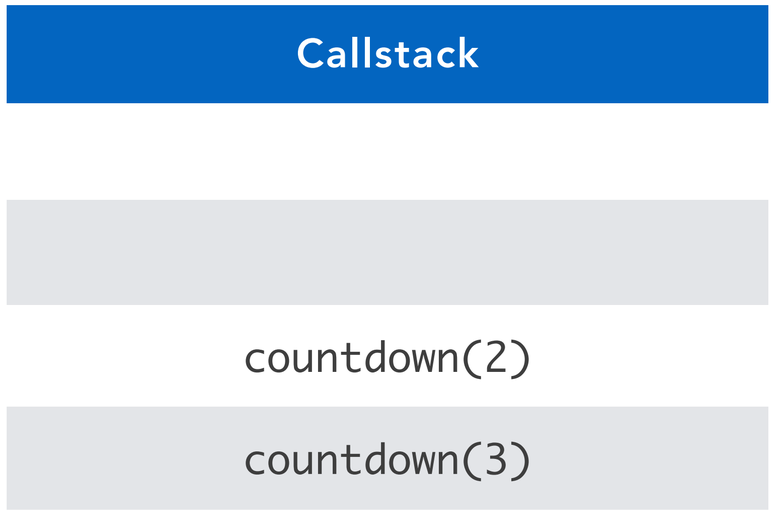
```
1   function countdown(num) {
2     // here's our stop condition, commonly known as the 'base case'
3     if (num < 1) {
4       console.log('done!');
5     }
6     // here's our 'recursive case'
7     else {
8       console.log(num);
9       countdown(num - 1);
10    }
11  }
12
13  countdown(3);
14
```



example: countdown

```
3
2
1
done!
```

```
1   function countdown(num) {
2     // here's our stop condition, commonly known as the 'base case'
3     if (num < 1) {
4       console.log('done!');
5     }
6     // here's our 'recursive case'
7     else {
8       console.log(num);
9       countdown(num - 1);
10    }
11  }
12
13  countdown(3);
14
```



example: countdown

```
3
2
1
done!
```

```
1   function countdown(num) {
2     // here's our stop condition, commonly known as the 'base case'
3     if (num < 1) {
4       console.log('done!');
5     }
6     // here's our 'recursive case'
7     else {
8       console.log(num);
9       countdown(num - 1);
10    }
11  }
12
13  countdown(3);
14
```

Callstack

countdown(3)

example: countdown

```
3
2
1
done!
```

```
1   function countdown(num) {
2     // here's our stop condition, commonly known as the 'base case'
3     if (num < 1) {
4       console.log('done!');
5     }
6     // here's our 'recursive case'
7     else {
8       console.log(num);
9       countdown(num - 1);
10    }
11  }
12
13  countdown(3);
14
```

Callstack

example: countdown

```
1   /* two takeaways from countdown: */
2
3   /* 1. you need to define a base case! */
4
5   /* 2. your recursive case must change the input to the function so that
6         you will eventually trigger the base case! */
7
8
9
10
11
12
13
14
```

Returning from recursive calls

```
1  /* recursion becomes more complicated when the function must return a
2     value */
3
4  /* good practice is to start by defining a base case */
5
6  /* base cases are often occur when there is a simple input that expects a
7     simple output (e.g., the sum of a single number is that number) */
8
9  /* test that the base case works before working with the recursive
10    case! */
11
12
13
14
```

example: factorial

```
/* define a function, factorial, that take a number and returns the
   factorial of that number */

/* as a reminder:
   0! === 1
   1! === 1
   2! === 2 (2 * 1)
   3! === 6 (3 * 2 * 1)
   4! === 24 (4 * 3 * 2 * 1)
   5! === 120 (5 * 4 * 3 * 2 * 1) */

/* what look like simple inputs/outputs we can use to build a base
   case? */

```

```
1
1
```

example: factorial

```
function factorial(num) {
  // base case: num is 0 or 1
  if (num === 0 || num === 1) {
    return 1;
  }
}

factorial(0);
factorial(1);
```

example: factorial

```
/* ok, base case is set, just need to remember that our recursive case
   has bring num closer and closer to 1 or 0 so we eventually
   hit our base case */

/* notice an interesting pattern!

   0! === 1
   1! === 1
   2! === 2 (2 * factorial(1))
   3! === 6 (3 * factorial(2))
   4! === 24 (4 * factorial(3))
   5! === 120 (5 * factorial(4)) */
```

undefined

example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     // TODO
8   }
9
10  /* it's best to write your recursive case using the simplest possible
11     input that will result in a recursive call */
12  let result = factorial(2);
13  console.log(result);
14
```

```
1
undefined
```

example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     // we know we have to call factorial again in the recursive case
8     // if num === 2, what do we get if we call factorial again with num - 1?
9     console.log(factorial(num - 1));
10  }
11
12  let result = factorial(2);
13  console.log(result);
14
```

```
2
undefined
```

example: factorial

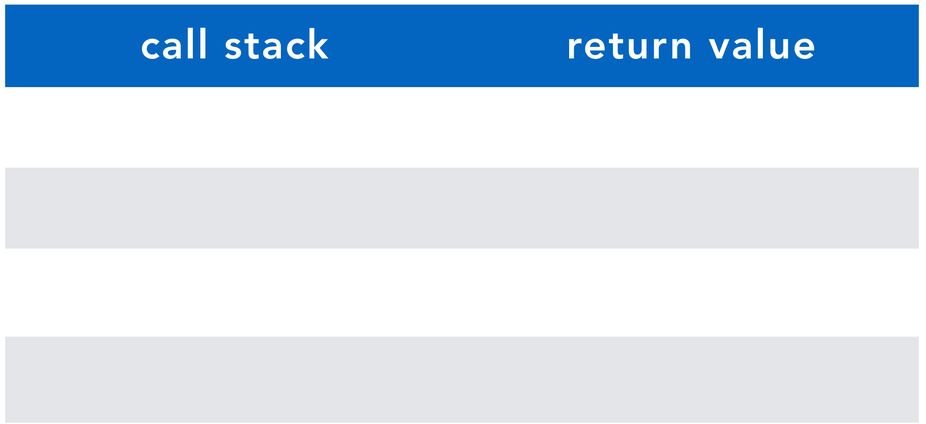
```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     // from that pattern we noticed earlier, we know 2! === 2 * 1!
8     console.log(num * factorial(num - 1));
9   }
10
11  let result = factorial(2);
12  console.log(result);
13
14
```

example: factorial

```
1  function factorial(num) {
2    // base case: num is 0 or 1
3    if (num === 0 || num === 1) {
4      return 1;
5    }
6    // recursive case: num must get closer to 0 or 1
7    // just have to return the result now
8    let result = num * factorial(num - 1);
9    return result;
10 }
11
12 let result = factorial(2);
13 console.log(result);
14
```

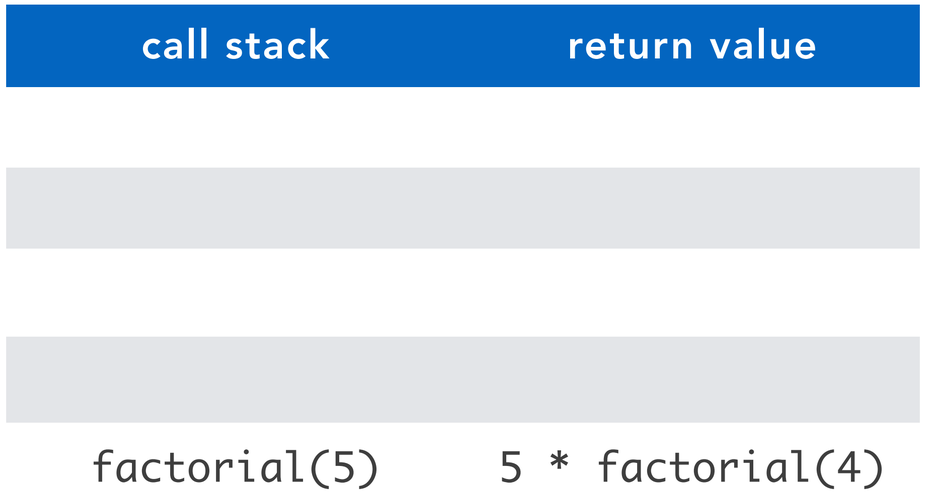
example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```



example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```



example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```

call stack	return value
factorial(4)	4 * factorial(3)
factorial(5)	5 * factorial(4)

example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```

call stack	return value
factorial(3)	3 * factorial(2)
factorial(4)	4 * factorial(3)
factorial(5)	5 * factorial(4)

example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```

call stack	return value
factorial(2)	2 * factorial(1)
factorial(3)	3 * factorial(2)
factorial(4)	4 * factorial(3)
factorial(5)	5 * factorial(4)

example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```

call stack	return value
factorial(1)	=> 1
factorial(2)	2 * factorial(1)
factorial(3)	3 * factorial(2)
factorial(4)	4 * factorial(3)
factorial(5)	5 * factorial(4)

example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```

call stack	return value
factorial(2)	2 * 1
factorial(3)	3 * factorial(2)
factorial(4)	4 * factorial(3)
factorial(5)	5 * factorial(4)

example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```

call stack	return value
factorial(2)	=> 2
factorial(3)	3 * factorial(2)
factorial(4)	4 * factorial(3)
factorial(5)	5 * factorial(4)

example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```

call stack	return value
factorial(3)	3 * 2
factorial(4)	4 * factorial(3)
factorial(5)	5 * factorial(4)

example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```

call stack	return value
factorial(3)	=> 6
factorial(4)	4 * factorial(3)
factorial(5)	5 * factorial(4)

example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```

call stack	return value
factorial(4)	4 * 6
factorial(5)	5 * factorial(4)

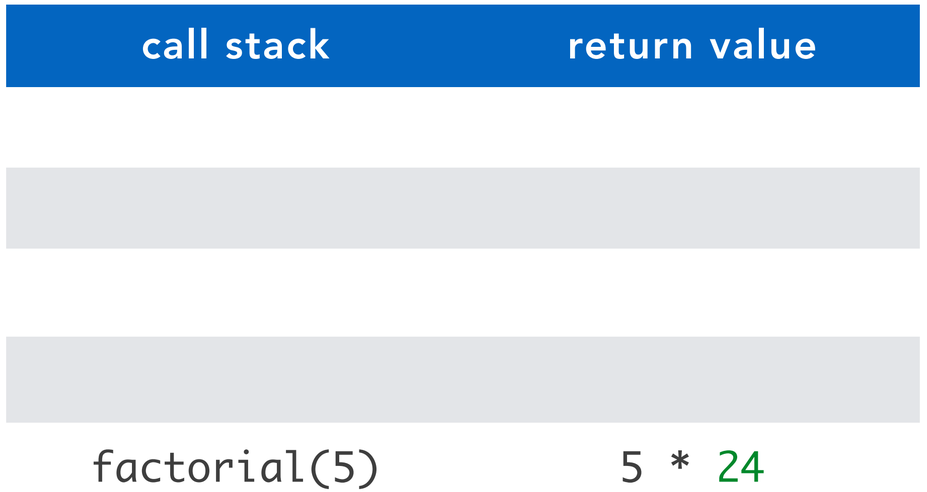
example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```

call stack	return value
factorial(4)	=> 24
factorial(5)	5 * factorial(4)

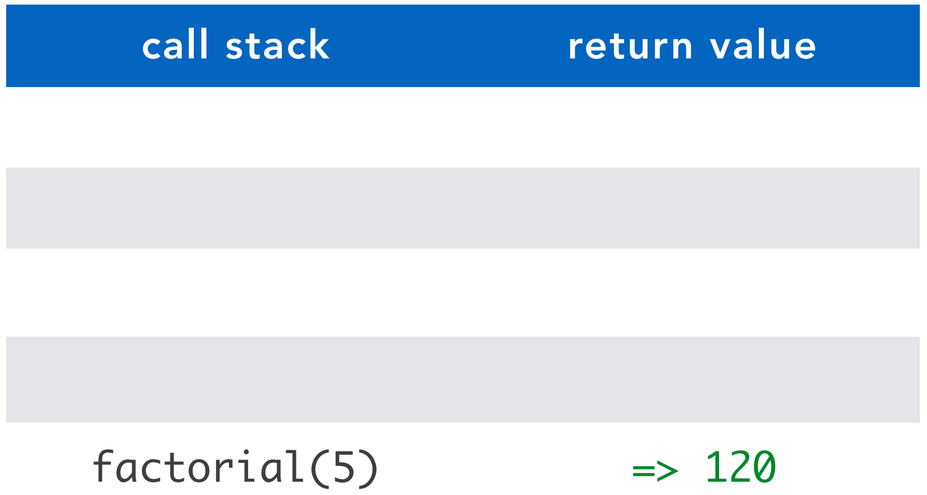
example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```



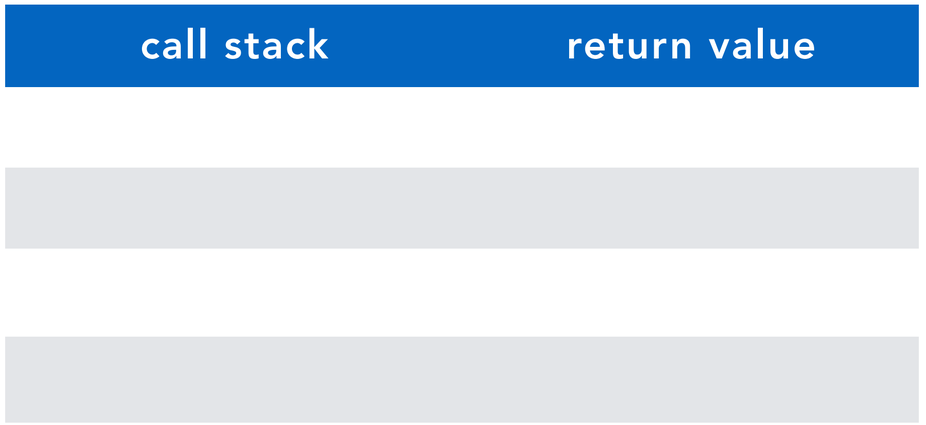
example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```



example: factorial

```
1   function factorial(num) {
2     // base case: num is 0 or 1
3     if (num === 0 || num === 1) {
4       return 1;
5     }
6     // recursive case: num must get closer to 0 or 1
7     let result = num * factorial(num - 1);
8     return result;
9   }
10
11  let result = factorial(5);
12  console.log(result);
13
14
```



example: factorial

```
1   /* three takeaways from factorial: */
2
3   /* 1. define your base case first, using simple inputs/outputs */
4
5   /* 2. define your base case, and test it using the simplest possible
6         input that results in one recursive call to the base case */
7
8   /* 3. test your function against more-complex inputs */
9
10
11
12
13
14
```

recursion and iterables

```
1  /* you can use recursion with any data type in JS */
2
3  /* if you're asked to recurse through arrays or strings, the base case
4     often occurs when the iterable is empty or has a length of one */
5
6  /* imagine finding the sum of numbers in an array */
7
8  sumArray([4]); // if array.length === 1, the sum is easy to calculate
9
10 /* if the base case required the iterable to have a length of 1 or 0, it
11    must mean that the recursive case has to reduce the length of the
12    iterable with every recursive call */
13
14 /* note: nested arrays can be approached differently; see next unit! */
```

other recursion hints

```
1   /* cannot emphasize enough: start with the base case! */
2
3   /* cannot emphasize enough: test recursive case with simplest possible
4      input that will result in one recursive call to the base case */
5
6   /* ask yourself: what type of thing should my function return? base case
7      and recursive case should return the same type of thing! */
8
9   /* use console.logs or debugger to debug */
10
11
12
13
14
```

Recap

```
/*
  - Definition of recursion
  - The call stack
  - countdown example
  - factorial example
  - Recursion and arrays, strings
  - Tips for approaching recursion problems
*/
```