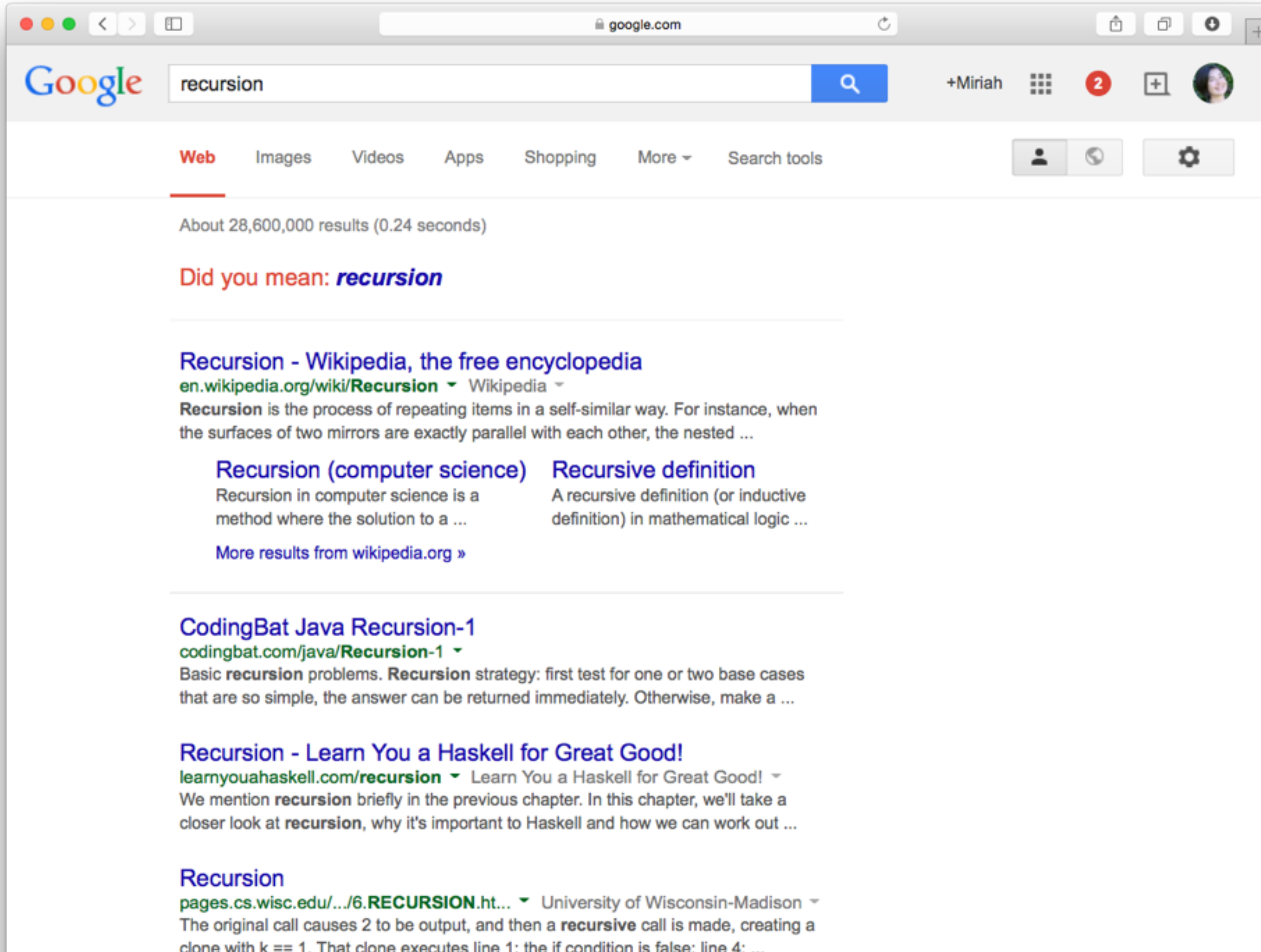
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Did you mean: recursion
Recursion - Wikipedia, the free encyclopedia
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Recursion is the process of repeating items in a self-similar way. For instance, when the surfaces of two mirrors are exactly parallel with each other, the nested ...
Recursion (computer science)
Recursion in computer science is a method where the solution to a ...
Recursive definition
A recursive definition (or inductive definition) in mathematical logic ...
More results from wikipedia.org »
CodingBat Java Recursion-1
codingbat.com/java/Recursion-1
Basic recursion problems. Recursion strategy: first test for one or two base cases that are so simple, the answer can be returned immediately. Otherwise, make a ...
Recursion - Learn You a Haskell for Great Good!
learnyouahaskell.com/recursion Learn You a Haskell for Great Good!
We mention recursion briefly in the previous chapter. In this chapter, we'll take a closer look at recursion, why it's important to Haskell and how we can work out ...
Recursion
pages.cs.wisc.edu/.../6.RECURSION.ht... University of Wisconsin-Madison
The original call causes 2 to be output, and then a recursive call is made, creating a clone with k == 1. That clone executes line 1: the if condition is false; line 4: ...

RECURSION

cs2420 | Introduction to Algorithms and Data Structures | Spring 2016

administrivia…

-assignment 4 due on Thursday at midnight

-partners?

-midterm next Tuesday

- -exam review questions out later this week

-no office hours today

last time…

selection vs **insertion**

	selection	insertion
WORST:	$O(N^2)$	$O(N^2)$
AVERAGE:	$O(N^2)$	$O(N^2)$
BEST:	$O(N^2)$	$O(N)$

selection vs **insertion**

	selection	insertion
WORST:	$O(N^2)$	$O(N^2)$
AVERAGE:	$O(N^2)$	$O(N^2)$
BEST:	$O(N^2)$	$O(N)$

WHICH ONE PERFORMS BETTER IN PRACTICE?

A) **selection**
B) **insertion**

what we want…

-a sorting algorithm that has **subquadratic** complexity

-swapping adjacent items removes exactly 1 inversion

45	-3	9	76	11	-8	0

SWAP REMOVES 1 INVERSION

-what if we consider swapping nonadjacent pairs?

45	-3	9	76	11	-8	0

SWAP REMOVES 7 INVERSION

-removes inversions not involved with the swap

shellsort

the simplest subquadratic sorting algorithm

shellsort

insertion sort, with a twist

1) set the **gap size** to **N/2**

2) consider the subarrays with elements at **gap size** from each other

3) do insertion sort on each of the subarrays

4) divide the **gap size** by 2

5) repeat steps 2 — 4 until the is **gap size** is <1

shellsort

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WHAT DOES THIS LOOK LIKE?

HOW DO WE DESCRIBE **INSERTION SORT** WITH RESPECT TO **SHELLSORT**?

```
void shellSort(int[] arr)
{
  for(gap = arr.length/2; gap > 0; gap /= 2)
  {
    for(i = gap; i < arr.length; i++)
    {
      val = arr[i];
      for(j = i-gap; j >= 0 && arr[j] > val; j -= gap)
        arr[j+gap] = arr[j];
      arr[j+gap] = val;
    }
  }
}
```

DIMINISHING GAP SEQUENCE

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ITEM TO BE INSERTED

DIMINISHING GAP SEQUENCE

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UNTIL THE INSERTION POSITION IS FOUND, SHIFT SORTED ITEMS

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```

ITEM TO BE INSERTED

INSERT ITEM

today…

-what is recursion? and some examples…

-driver methods

-the overhead of recursion

re·cur·sion

[ri-**kur**-zh*uh* n]
noun

see *recursion.*

-**recursion** is a problem solving technique in which the solution is defined in terms of a simpler (or smaller) version of the problem

-break the problem into smaller parts

-*solve the smaller problems*

-*combine the results*

-a recursive method calls itself

-some functions are easiest to define recursively

```
sum(N) = sum(N-1) + N
```

-there must be at least one *base case* that can be computed without recursion

-any recursive call must make progress towards the base case!

a simple example

`sum(N) = sum(N-1) + N`

```
public static int sum(int n) {
  if(n == 1)
    return 1;
  return sum(n-1) + n;
}
```

a simple example

`sum(N) = sum(N-1) + N`

```
public static int sum(int n) {
  if(n == 1)
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  return sum(n-1) + n;
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FIX TO HANDLE ZERO OR NEGATIVE VALUES. . .

a simple example

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HOW CAN WE SOLVE THE SAME PROBLEM WITHOUT RECURSION?

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FIX TO HANDLE ZERO OR NEGATIVE VALUES. . .

HOW CAN WE SOLVE THE SAME PROBLEM WITHOUT RECURSION?

WHICH IS BETTER, THE RECURSIVE SOLUTION OR THE ALTERNATIVE?

exercise 1

-how to compute **N!**

N! = N * N-1 * N-2 * ... * 2 * 1

exercise 1

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-how would you compute this using a for-loop?

exercise 1

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  N! = N * N-1 * N-2 * ... * 2 * 1

-how would you compute this using a for-loop?

-how would you compute this using recursion?

  -think about:

    -what is the base case?

    -what is recursive?

exercise 1

-how to compute **N!**

N! = N * N-1 * N-2 * … * 2 * 1

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-how would you compute this using recursion?

-think about:

-what is the base case?

-what is recursive?

A) **c**
B) **log N**
C) **N**
D) **N log N**
E) **N^2**
F) **N^3**

WHAT IS THE COMPLEXITY OF THE FOR-LOOP METHOD?

exercise 1

-how to compute **N!**

N! = N * N-1 * N-2 * ... * 2 * 1

-how would you compute this using a for-loop?

-how would you compute this using recursion?

-think about:

-what is the base case?

-what is recursive?

A) **c**
B) **log N**
C) **N**
D) **N log N**
E) **N^2**
F) **N^3**

WHAT IS THE COMPLEXITY OF THE RECURSIVE METHOD?

exercise 2

```
public static int divide(int a, int b)
{
   ...
}
```

HINT: **9/2 = 1 + (7/2)**

exercise 2

- write a recursive method that computes **A/B**
  - do integer division
  - **/** operator not allowed, can only use **-**
  - don’t worry about negative input or divide-by-zero

```
public static int divide(int a, int b)
{
  ...
}
```

HINT: **9/2 = 1 + (7/2)**

-recursion often seems like MAGIC

- -use this to your advantage

-when writing a recursive method, just assume that the function you're writing already works, so you can use it to help solve the problem

-once you've worked out the recursion, think about the base case, and you're done

driver methods

divide and conquer

- **divide and conquer** is an important problem solving technique that makes use of recursion
  - **divide:** smaller problems are solved recursively (except for base cases!)
  - **conquer:** solutions to the subproblems form the solution to the original problem

- typically, an algorithm containing more than one recursive call is referred to as divide and conquer

- subproblems are usually disjoint (non-overlapping)

exercise 3
binary search (recursive)

- write a recursive method to perform a binary search
  - assume an (ascending) sorted list

exercise 3

binary search (recursive)

-write a recursive method to perform a binary search

  -assume an (ascending) sorted list

-HINT

  -check if middle item is what we're looking for

    -if so, return true

  -else, figure out if item is the left or right half

    -repeat on that half

  -base case(s)???

- recursive methods often have unusual parameters
  - at the top level, we just want:

```
binarySearch(arr, item);
```

  - but in reality, we have to call:

```
binarySearch(arr, item, 0, arr.length-1);
```

- **driver methods** are wrappers for calling recursive methods
  - driver makes the initial call to the recursive method, knowing what parameters to use
  - is *not* recursive itself

```
public static boolean binarySearch(arr, item){
  return binarySearchRecursive(
    arr, item, 0, arr.length-1);
}
```

-another useful feature of driver methods is error checking (or, validity checks)

-do the error checking *only* in the driver method, instead of redundantly doing it every time in the recursion

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WHAT IS SOMETHING TO CHECK FOR IN OUR BINARY SEARCH METHOD?

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-do the error checking *only* in the driver method, instead of redundantly doing it every time in the recursion

WHAT IS SOMETHING TO CHECK FOR IN OUR BINARY SEARCH METHOD?

```
public static boolean binarySearch(arr, item){
  if (arr == null) // only check this once
    return false;

  return binarySearchRecursive(
    arr, item, 0, arr.length-1);
}
```

overhead of recursion

method calls

-every time a method is invoked, a unique “frame” is created

- -contains local variables and state
- -put on the **call stack**

-when that method returns, execution resumes in the calling method

-this is how methods know where to return to!

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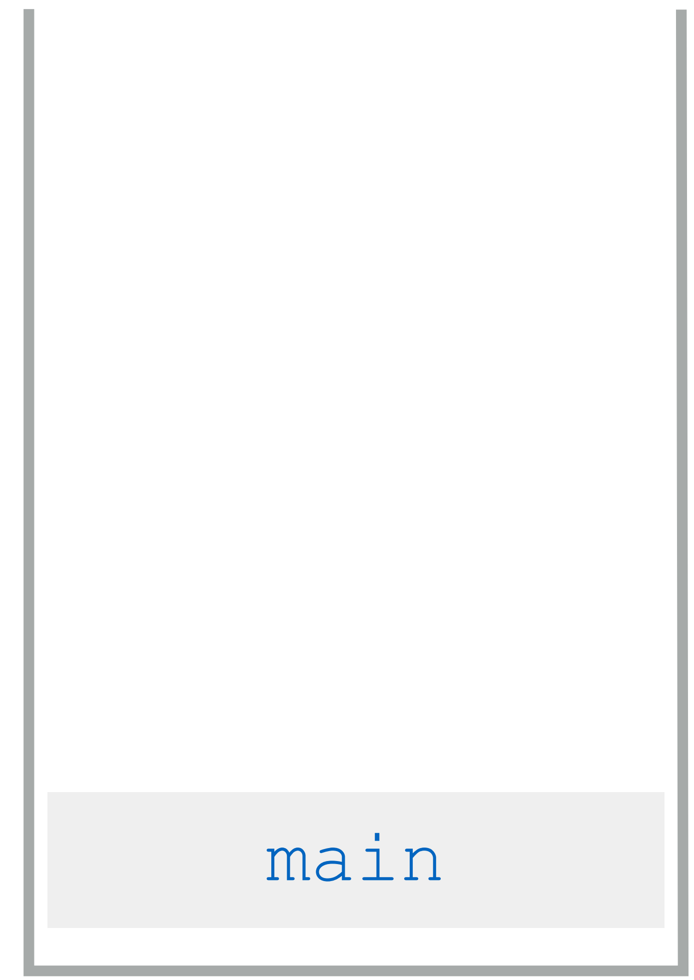
recursive calls

- create multiple frames of the same method
  - but each frame has different arguments



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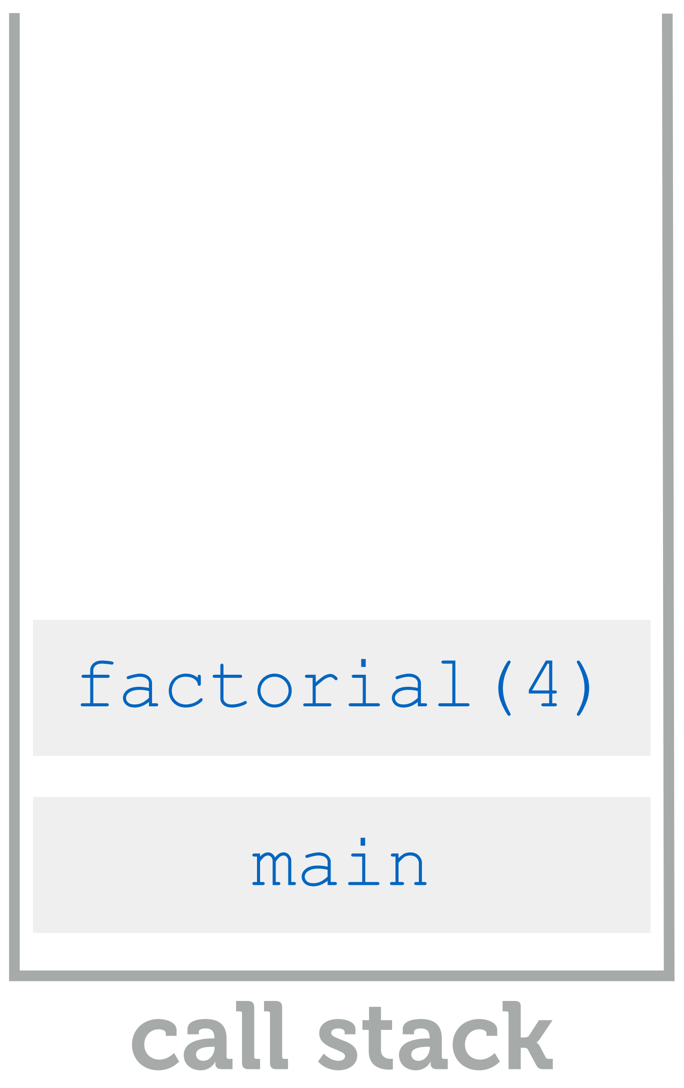

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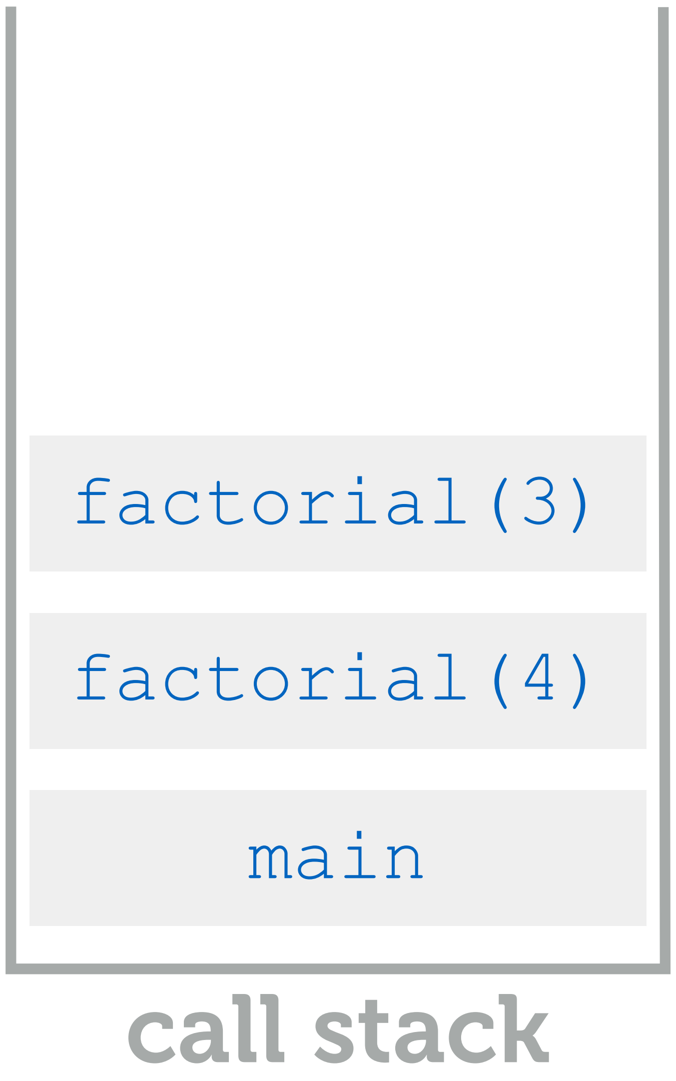

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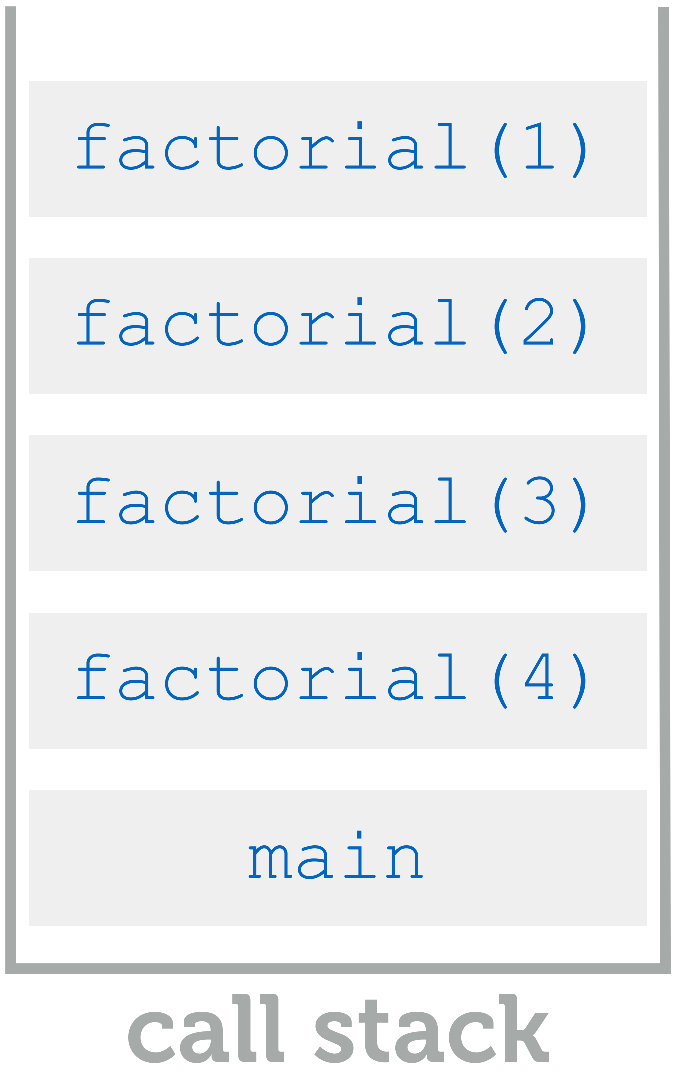

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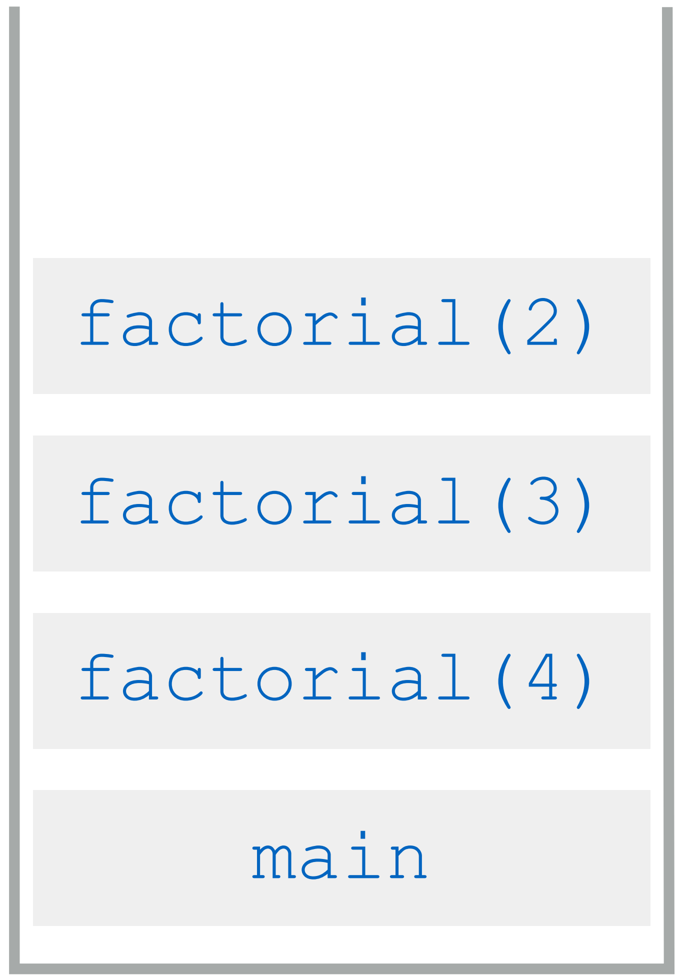

call stack

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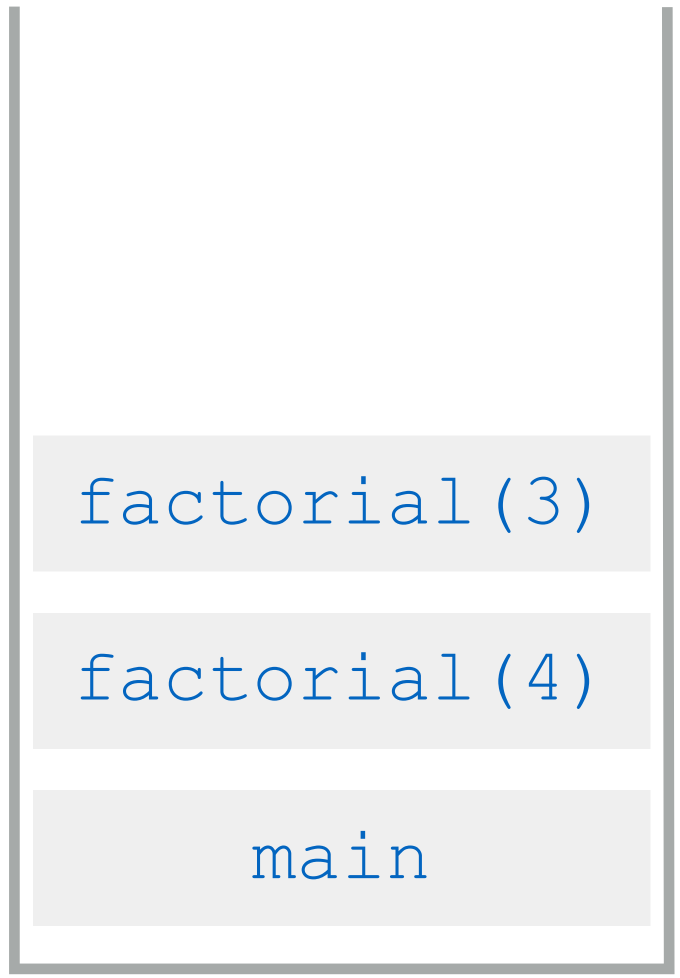

call stack

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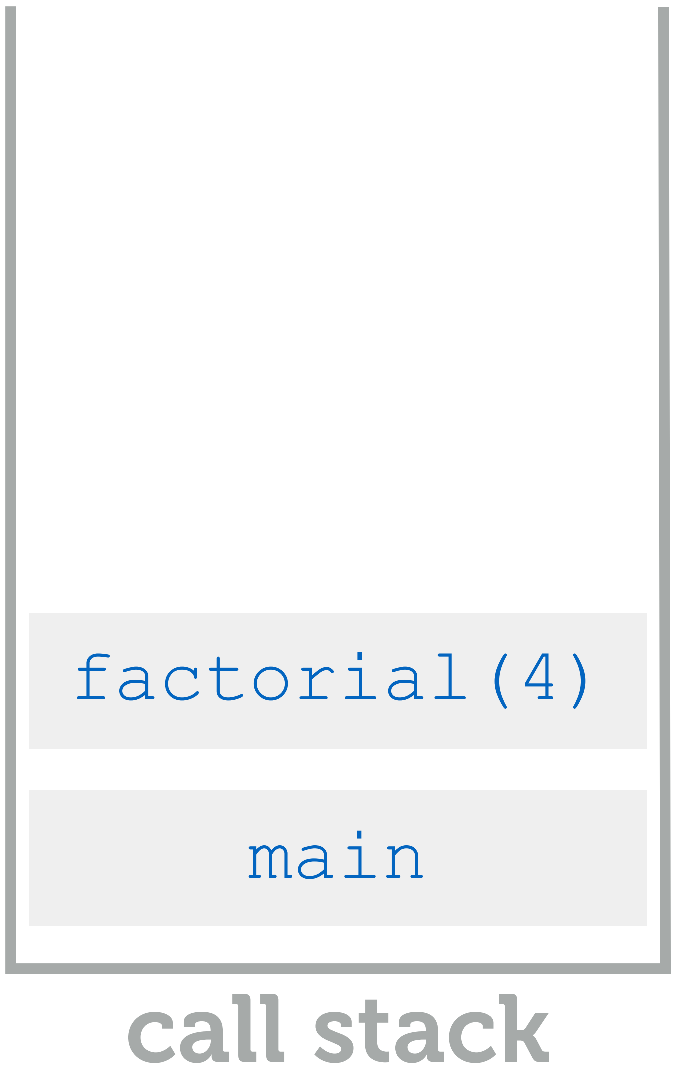

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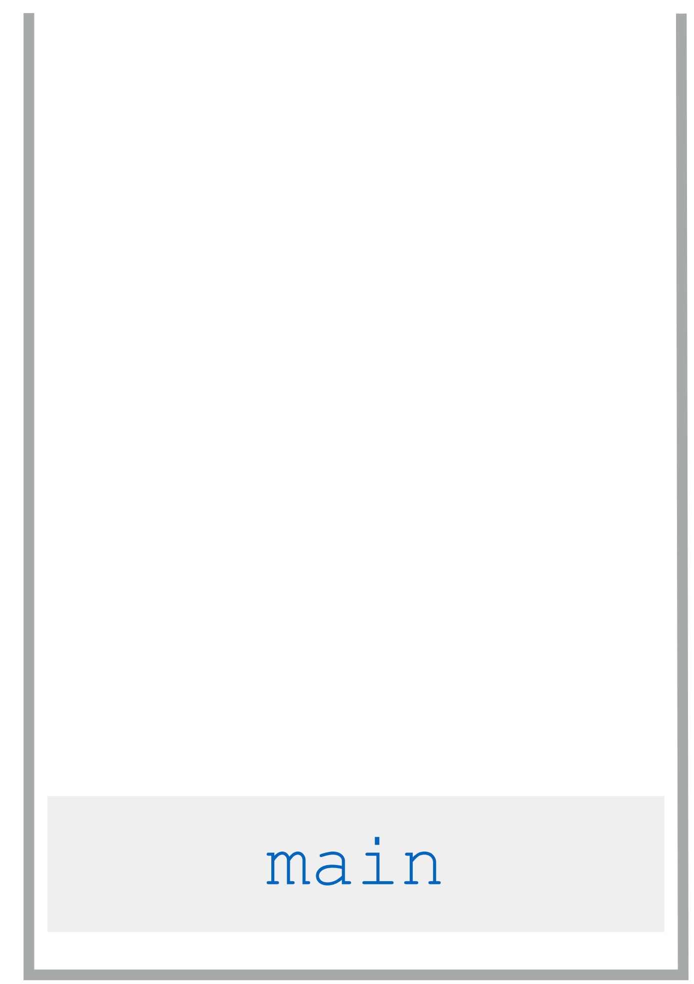

call stack

recursion, beware

-do not use recursion when a simple loop will do

- -growth rates may be the same, but…
- -…there is a lot of overhead involved in setting up the method frame
  - -*way more overhead than one iteration of a for-loop*

-do not do redundant work in a recursive method

- -move validity checks to a driver method

-too many recursive calls will overflow the call stack

- -stack stores state from all preceding calls

recap

4 recursion rules

1. always have at least one case that can be solved without using recursion

2. any recursive call must progress toward a base case

3. always assume that the recursive call works, and use this assumption to design your algorithms

4. never duplicate work by solving the same instance of a problem in separate recursive calls

next time…

-reading

-chapters 7 & 8.5 - 8.8 (recursion, mergesort, & quicksort)

-homework

-assignment 4 due Thursday

-(short) midterm review on Thursday