

# Collections, Part One

`console.h, cout` **and** `endl`

- Some people running Windows have been having issues with the console window quickly disappearing
- It appears that for many people the issue can be solved doing one or both of the following:
  - Downloading the latest version Java
  - Passing `endl` to `cout` at least once in your program

# Where are we in the course?

- For the moment we are done with C++ specific features
- Today we start learning about common data structures used in Computer Science
- After this we have...
  - Advanced Recursion
  - Algorithmic Analysis and Sorting
  - Implementing data structures
  - Graphs and Graph Algorithms

# Organizing Data

- In order to model and solve problems, we have to have a way of representing structured data.
- We need ways of representing concepts like
  - sequences of elements,
  - sets of elements,
  - associations between elements,
  - etc.

# Collections

- A **collection class** (or **container class**) is a data type used to store and organize data in some form.
- Understanding and using collection classes is critical to good software engineering.
- Today and next week is dedicated to exploring different collections and how to harness them appropriately.
- We'll discuss efficiency issues and implementations later on.

# Collections

- There are TONS of C++ libraries for collection classes
  - General Purpose: STL, Boost
  - Most companies have their own libraries
- So which library should we teach you?
- Because there are so many libraries, we think it's best to focus on skills and concepts, rather than on one specific library.
-

# TokenScanner

- The **TokenScanner** class can be used to break apart a string into smaller pieces.
- Construct a `TokenScanner` to piece apart a string as follows:

```
TokenScanner scanner (str) ;
```

- Configure options (ignore comments, ignore spaces, add operators, etc.)
- Use the following loop to read tokens one at a time:

```
while (scanner.hasMoreTokens ()) {  
    string token = scanner.nextToken ();  
    /* ... process token ... */  
}
```

- Check the documentation for more details; there are some really cool tricks you can do with the `TokenScanner`!

# Text Parsing

- TONS of websites that you can download data from in the form of “comma-separated-values” (csv) files.
  - e.g. Financial Data, Climate data
- Problem: Have a string consisting of a long sequence of numbers separated by commas.
- Goal: Extract numbers and calculate their average
- **How tough would this be using string libraries?**

ComputeSum.cpp  
(On Computer)



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.
- Only the top of the stack can be accessed; no other objects in the stack are visible.
- Example: Function calls



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271

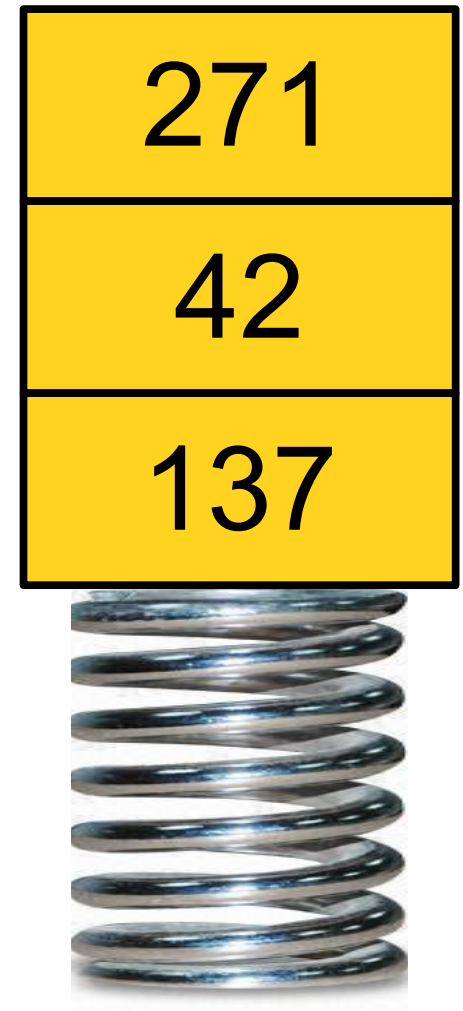
42

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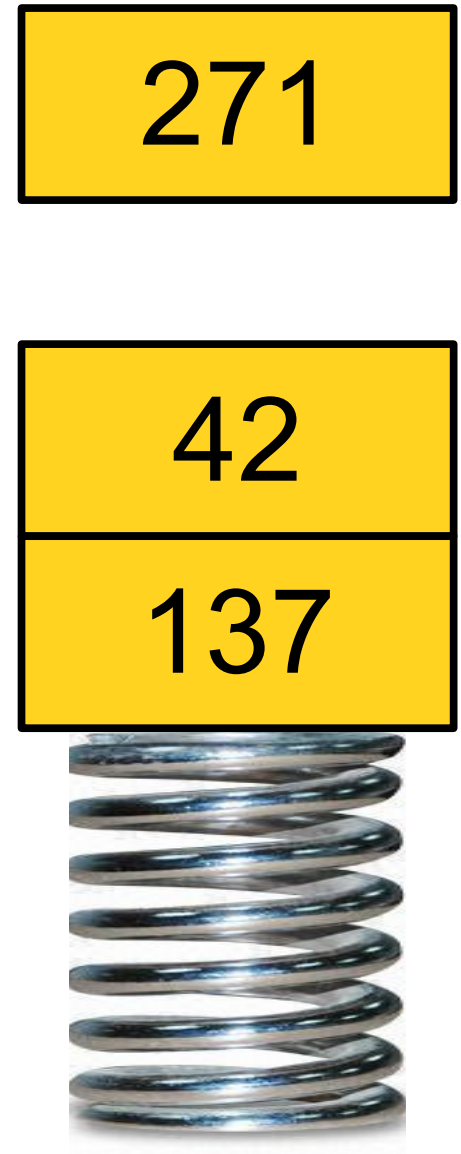
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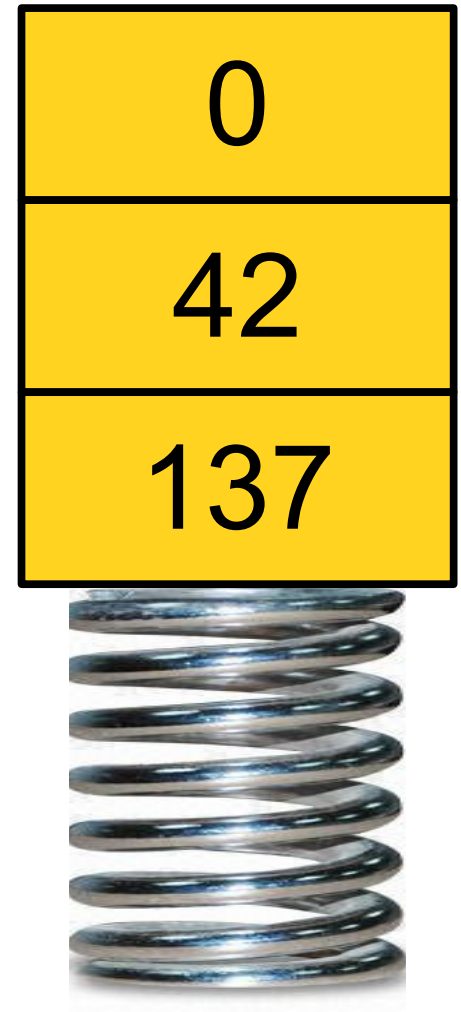
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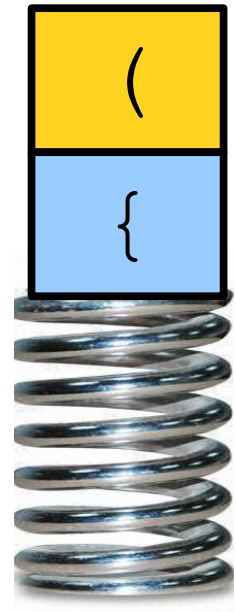
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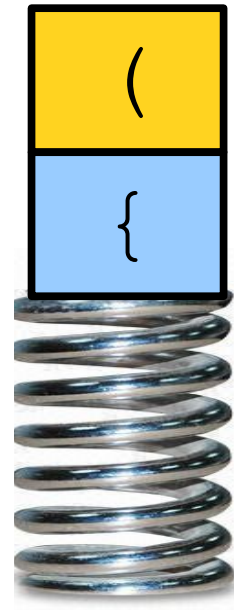
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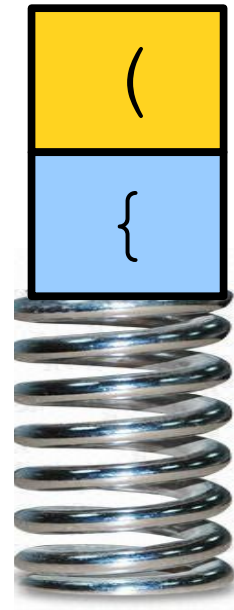
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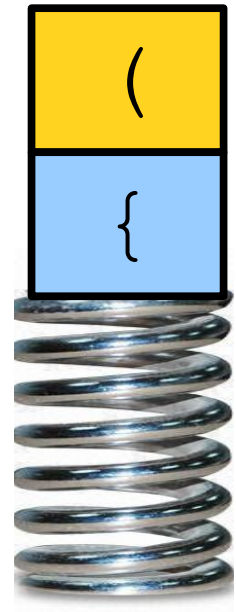
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int foo() { if (x ^ (y + z[1]) < 137) { x = 1; } }
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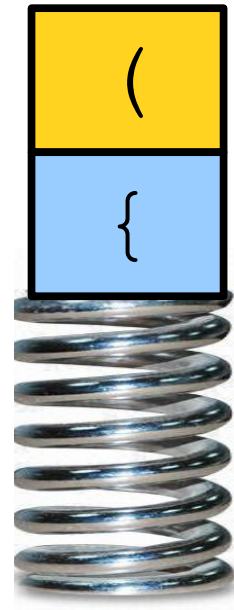
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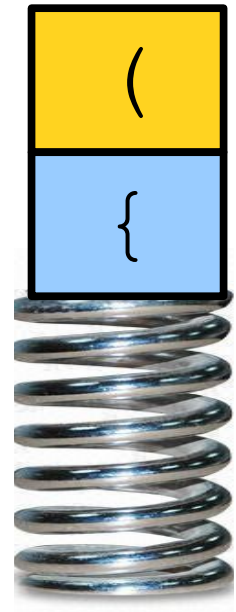
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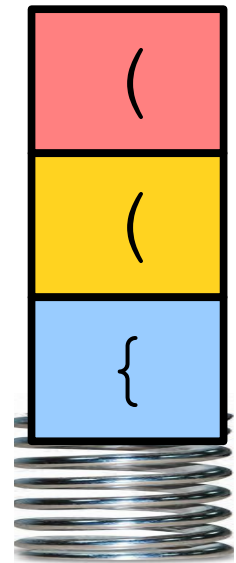
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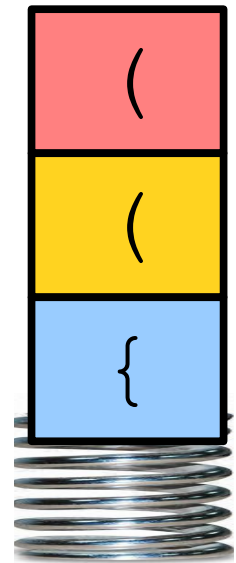
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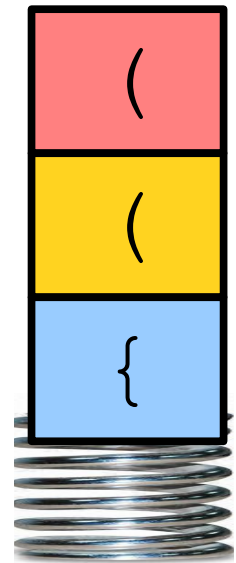
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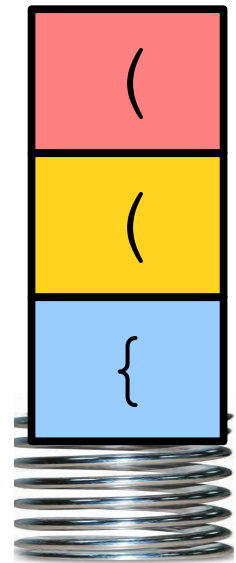
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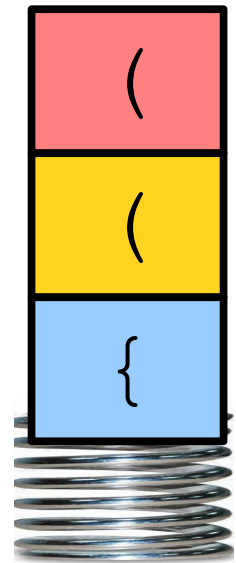
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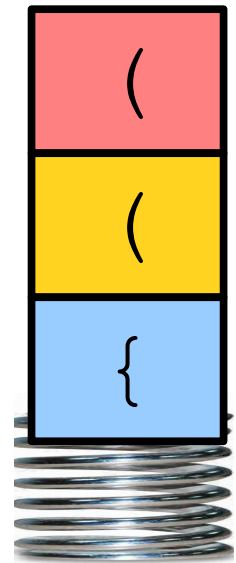
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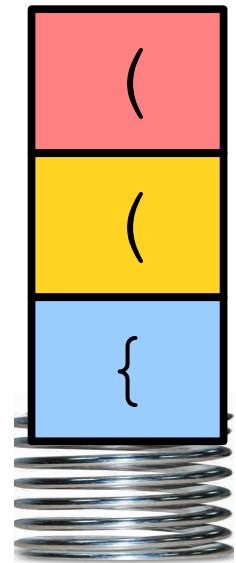
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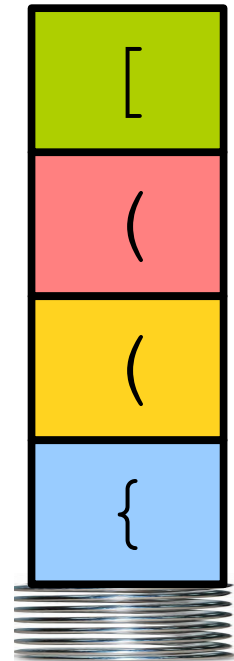
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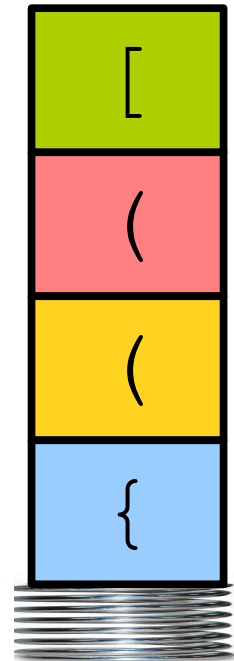
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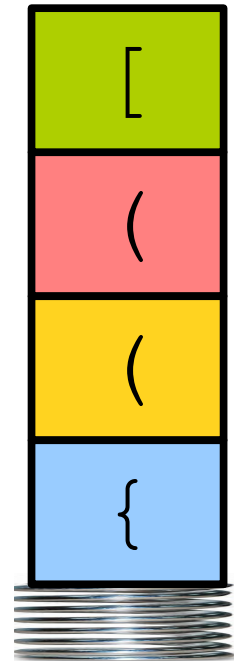
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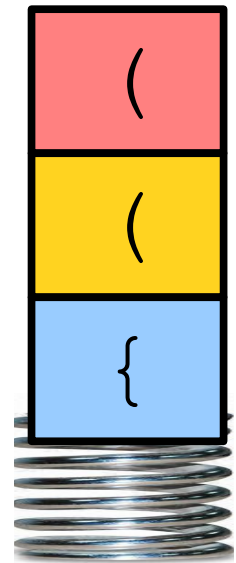
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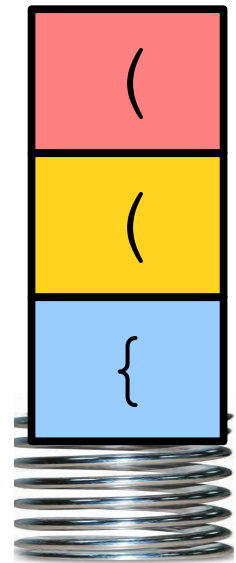
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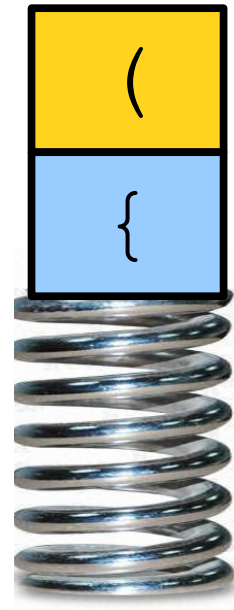
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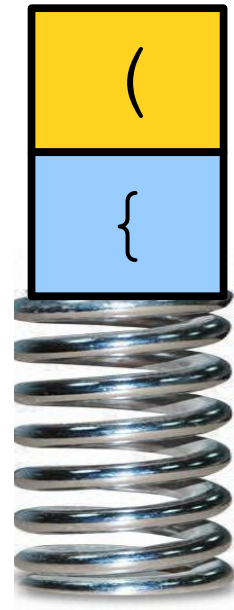
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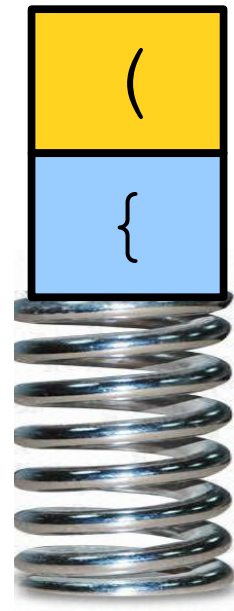
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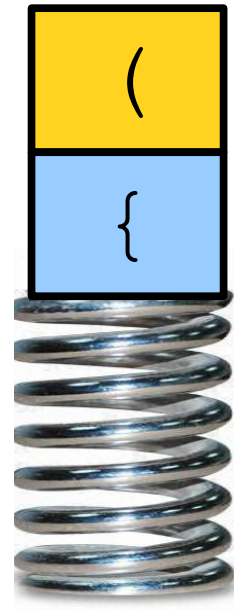
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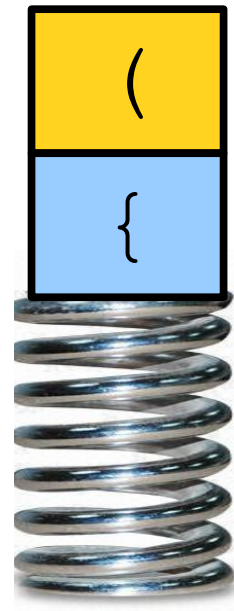
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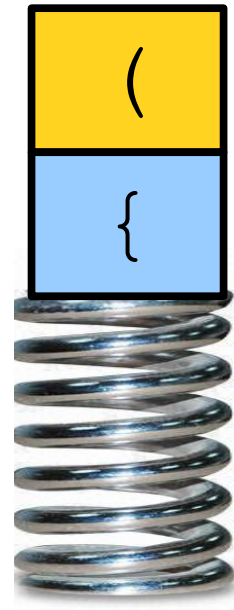




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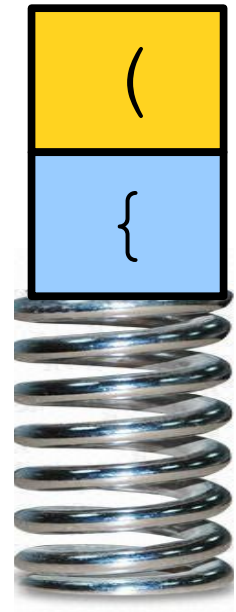
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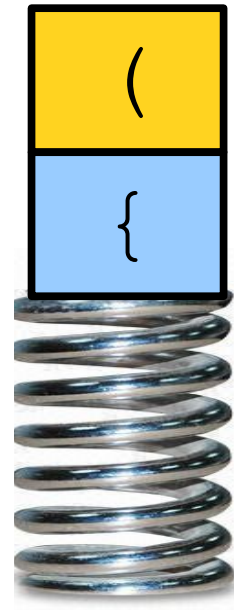
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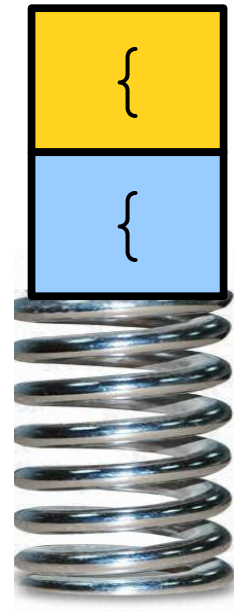
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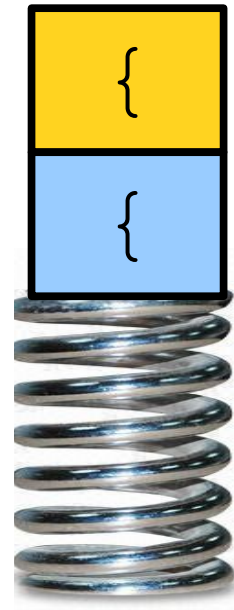
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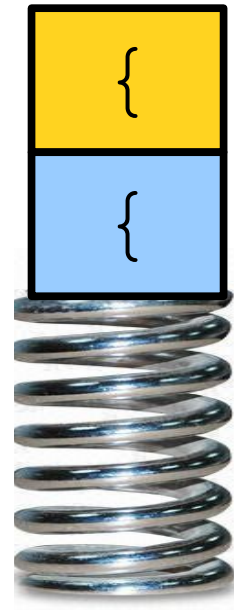
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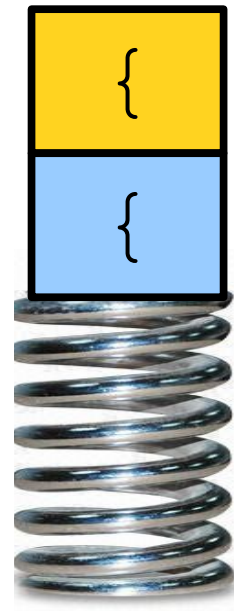
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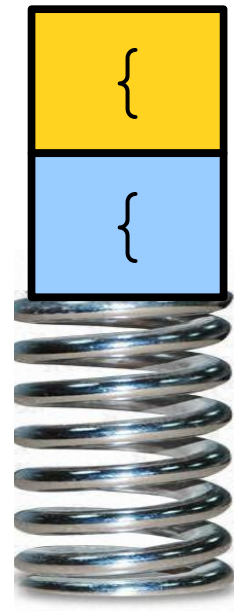
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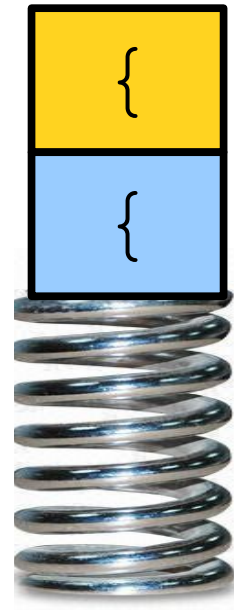
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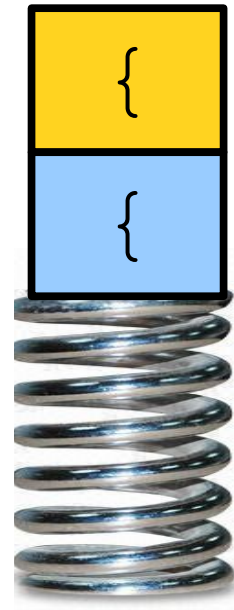
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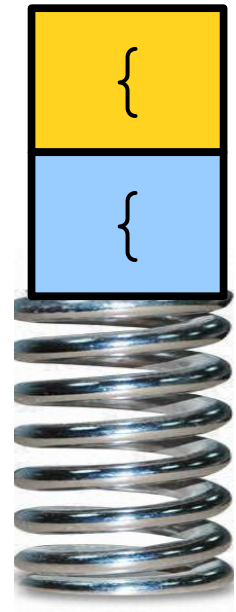
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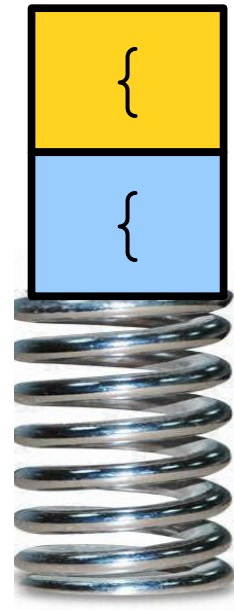
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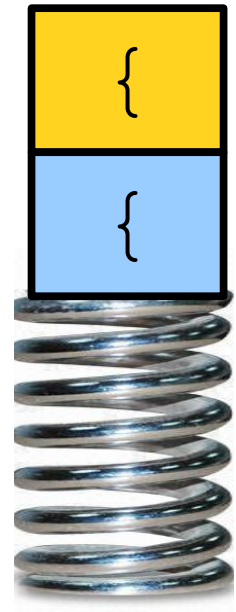
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Balancing Parentheses  
(On Board)



# A Few Functions to Make Life Easier...

```
bool isLeftParen(char ch) {  
    return ch == '(' || ch == '{' || ch == '[';  
}
```

```
bool isRightParen(char ch) {  
    return ch == ')' || ch == '}' || ch == ']';  
}
```

```
bool isMatchingParen(char left, char right) {  
    return (left == '(' && right == ')') ||  
           (left == '[' && right == ']') ||  
           (left == '{' && right == '}');  
}
```



# **Combining** TokenScanner **and** Stack: Evaluating Expressions

# Evaluating Expressions

- We want to be able to evaluate simple arithmetic expressions composed of integers and the four basic arithmetic operators “+,-,\*,/”
  - $5 * 20 - 8 + 5$
- Proposed algorithm: just evaluate the expression from left to right.
  - $5 * 8 + 7 = 40 + 7 = 47$
  - $1 + 2 + 4 = 3 + 4 = 7$
- It works...or does it?
  - $7 + 5 * 8 = 12 * 8 = 96???$

# Evaluating Expressions

- Evaluating expressions is much trickier than it might seem due to issues of precedence.
  - $1 + 3 * 5 - 7 = 9$
- We can't just evaluate operators from left to right
- How do we evaluate an expression?

# The Challenge

1	3	7		+		4	2		×		2	7	1
---	---	---	--	---	--	---	---	--	---	--	---	---	---

# Evaluating Expressions

- Two separate concerns in evaluating expressions:
  - **Scanning** the string and breaking it apart into its constituent components (*tokens*).
  - **Parsing** the tokens to determine what expression is encoded.
- We can scan the string with the `TokenScanner`. How might we handle parsing?

# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



**Operands**

# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



**Operands**



**Operators**



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



**Operands**



**Operators**

# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



Operands

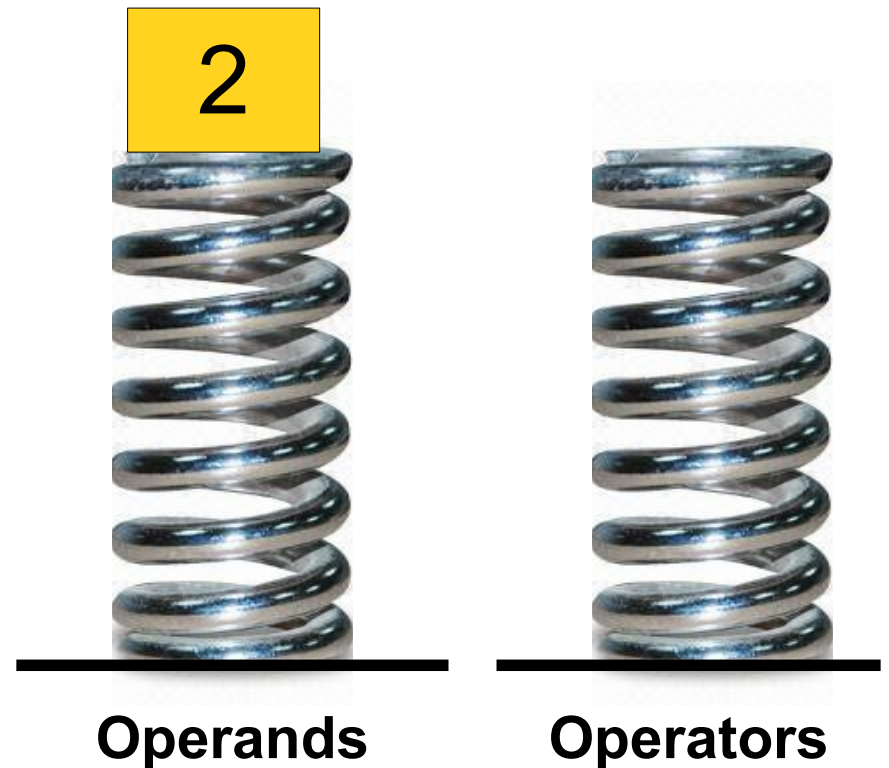


Operators

# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

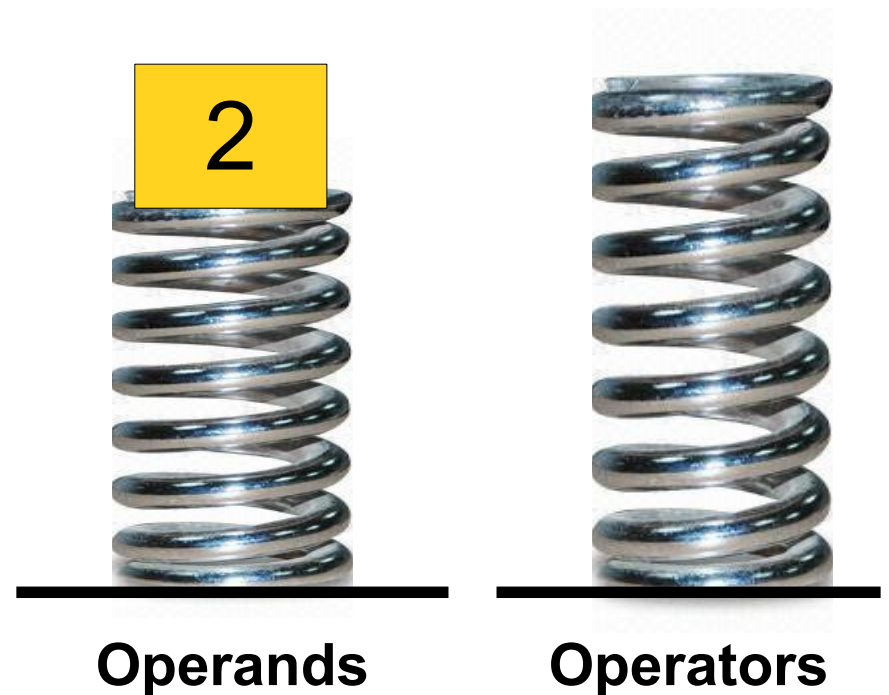
+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

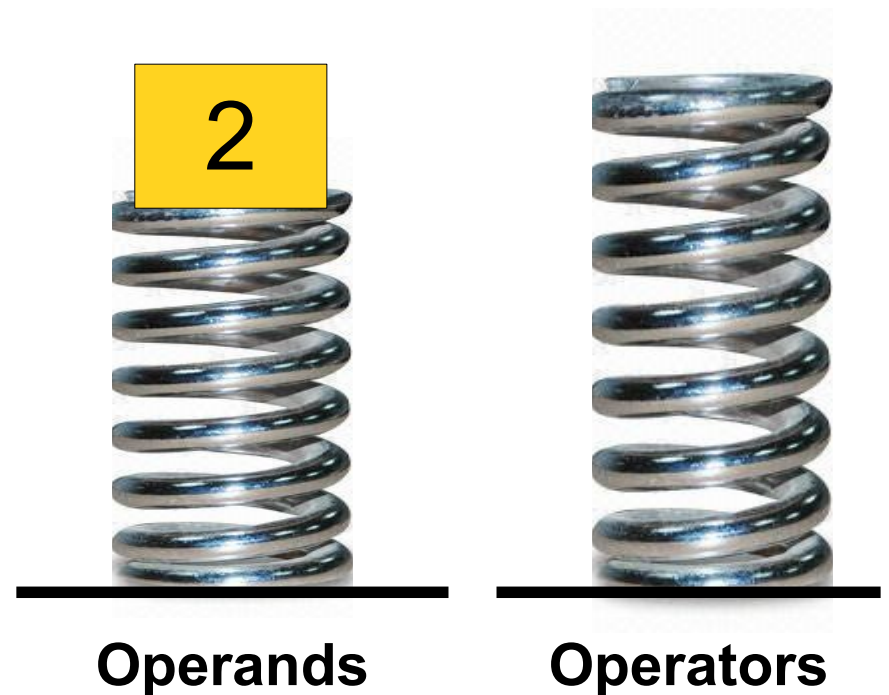
+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

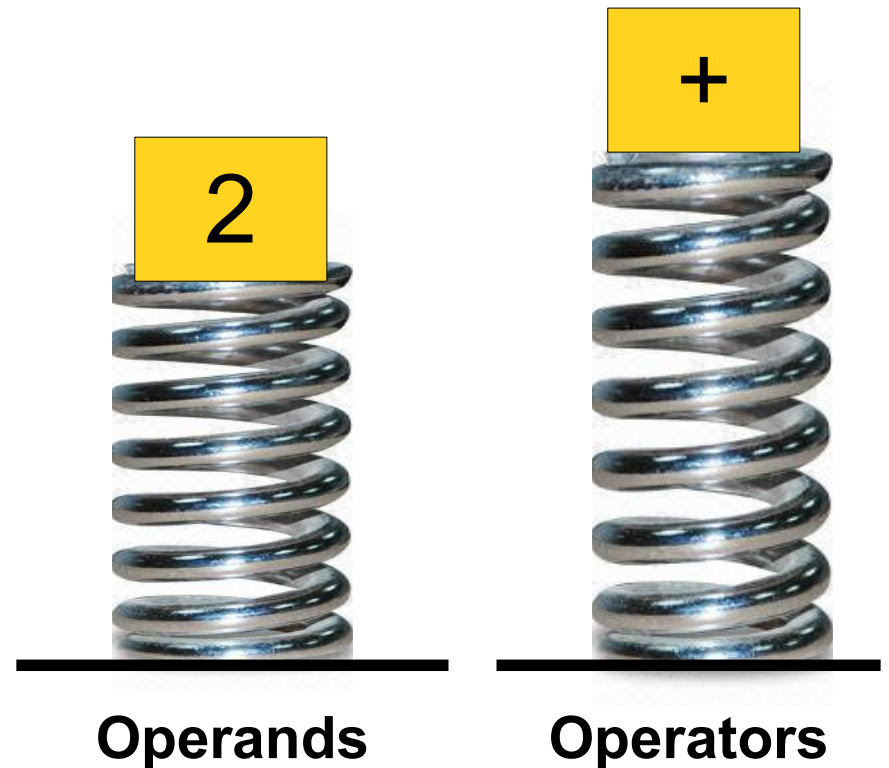
+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

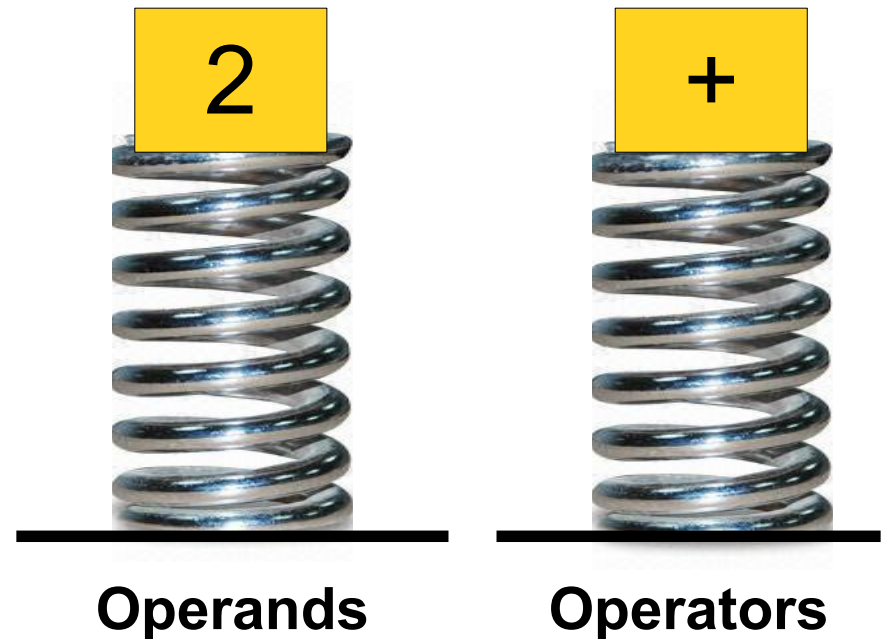
3	*	5	-	6	/	2
---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

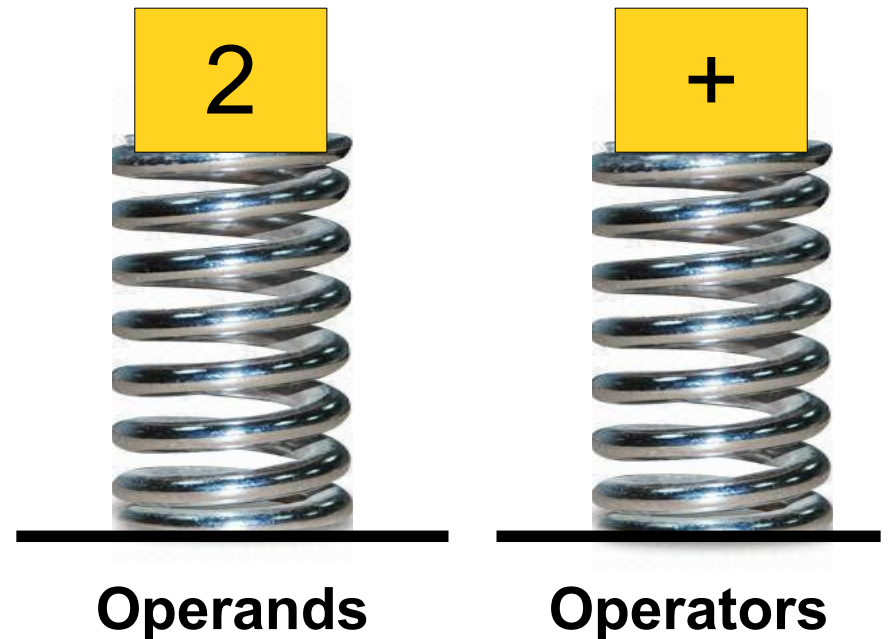
3	*	5	-	6	/	2
---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

3	*	5	-	6	/	2
---	---	---	---	---	---	---

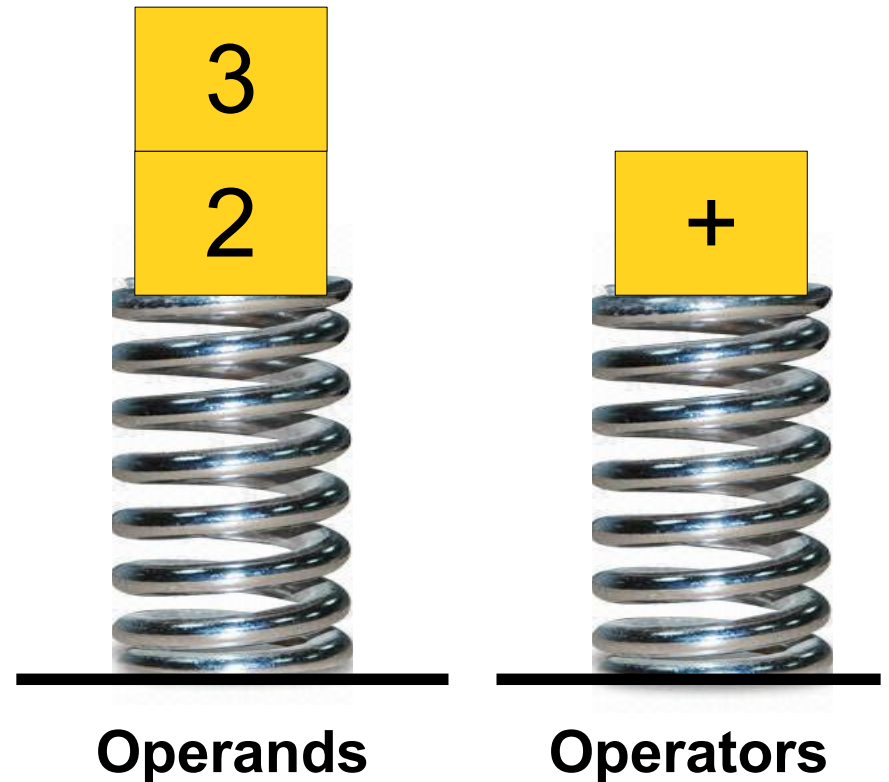




# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

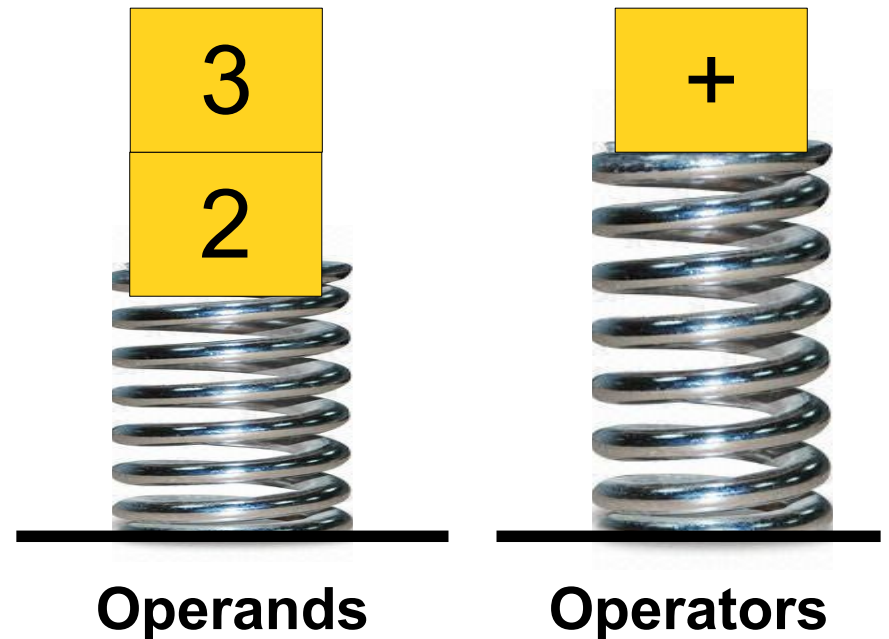
*	5	-	6	/	2
---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

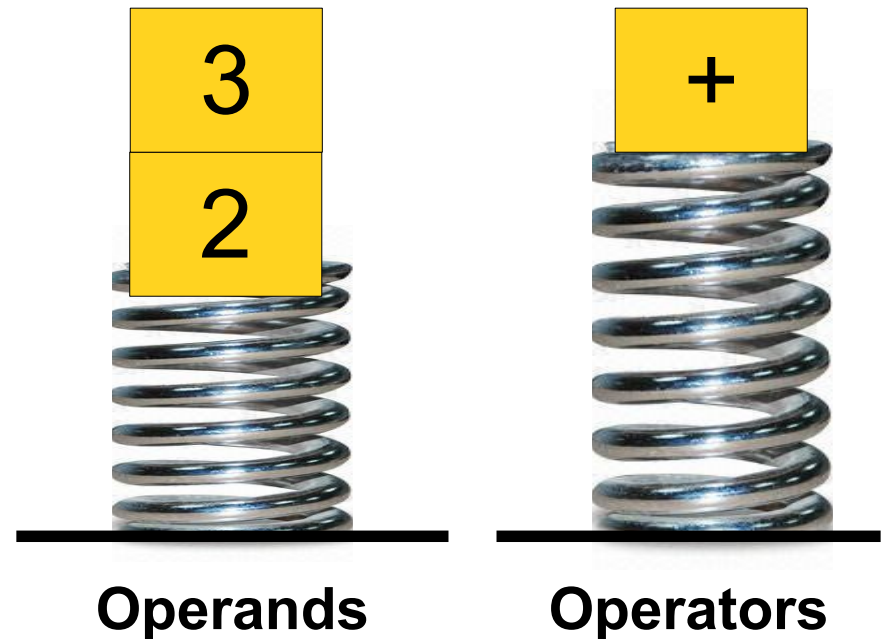
*	5	-	6	/	2
---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

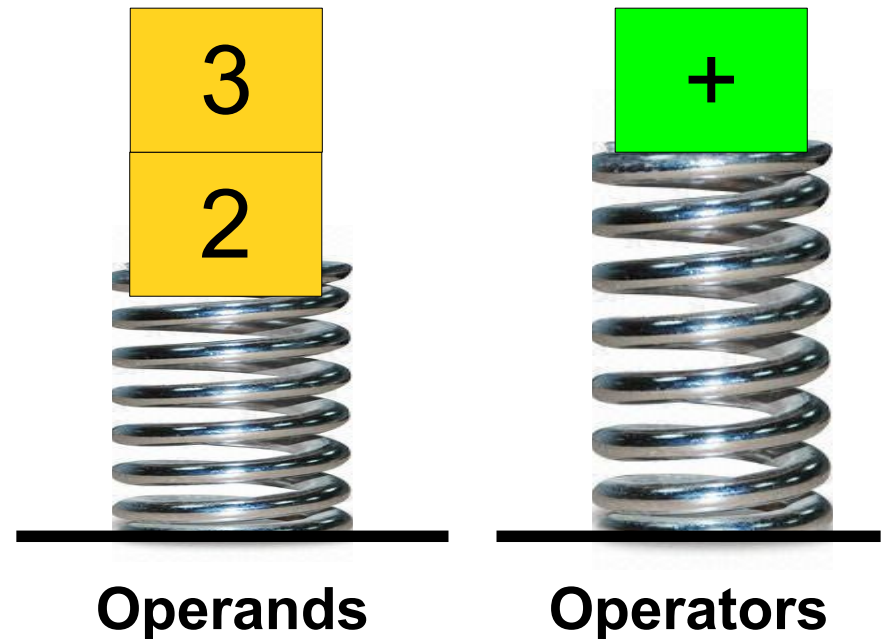
*	5	-	6	/	2
---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

*	5	-	6	/	2
---	---	---	---	---	---

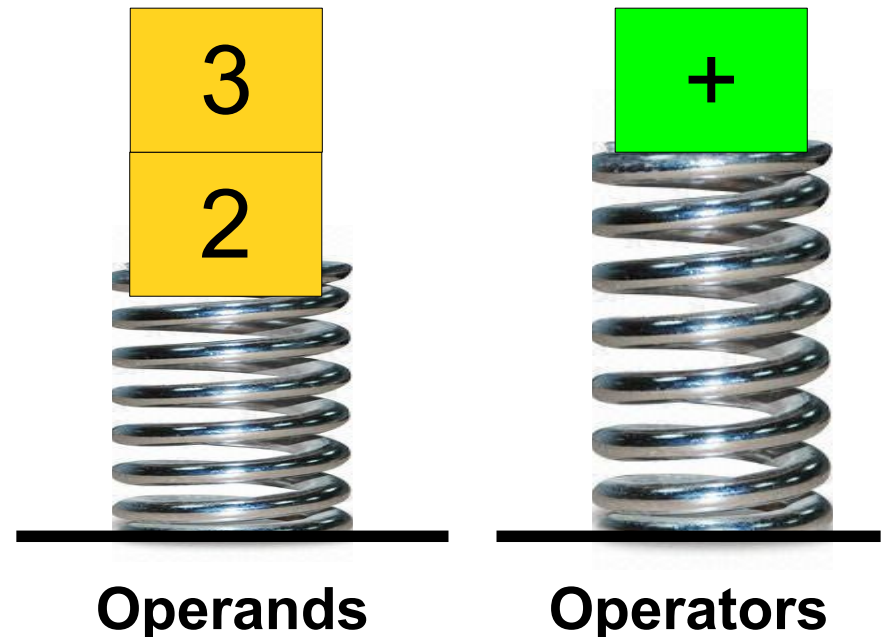


# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

*	5	-	6	/	2
---	---	---	---	---	---

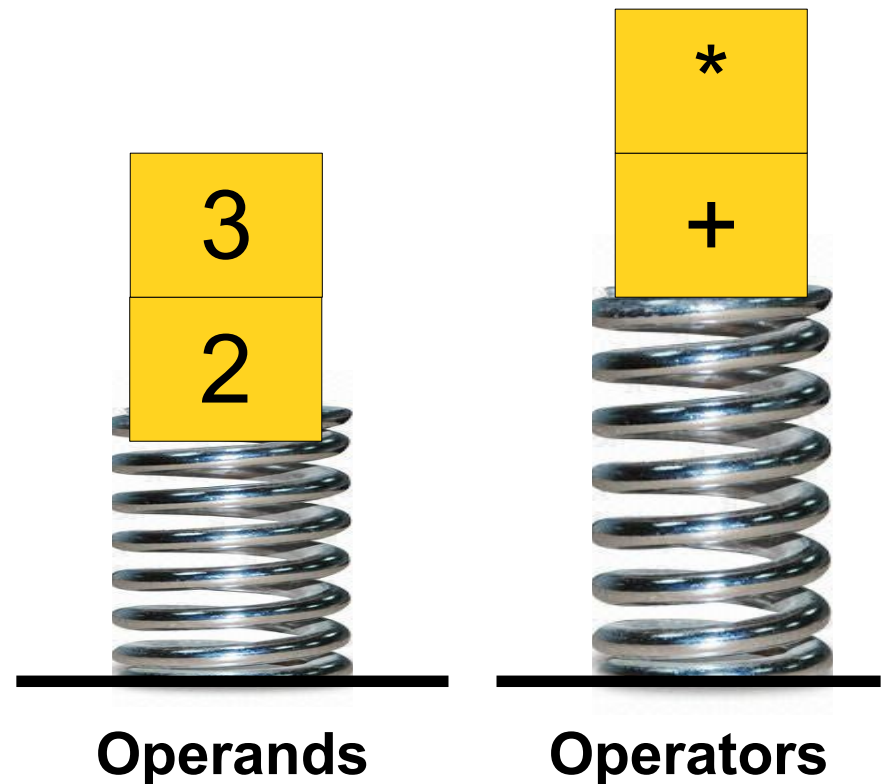
Multiplication has higher precedence than addition, so we will postpone the addition until after we've done the multiplication.



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

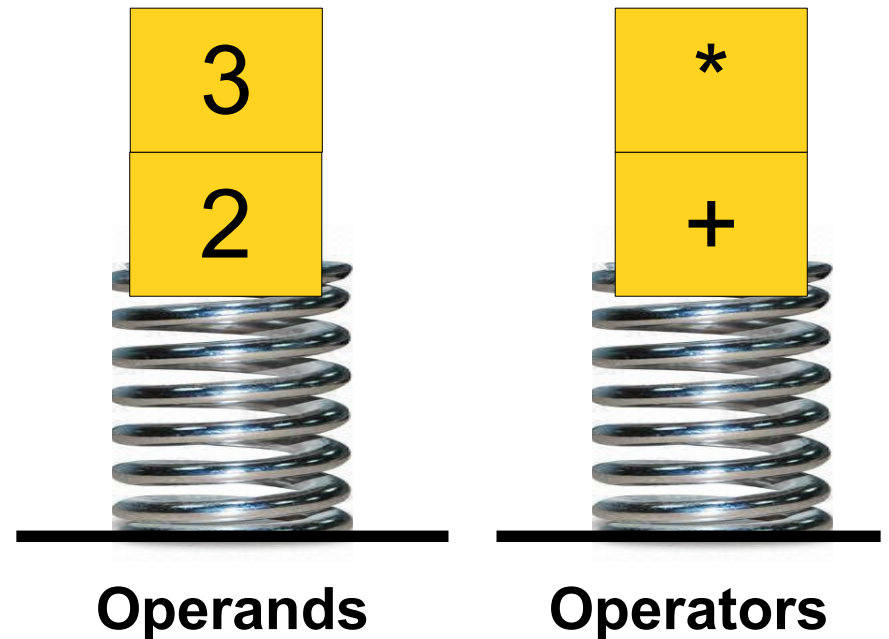
5	-	6	/	2
---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

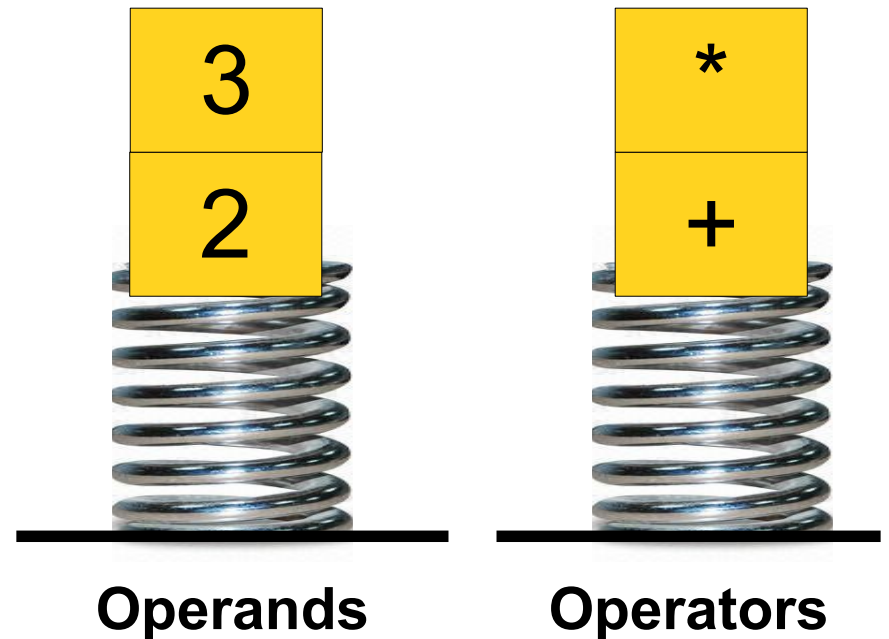
5	-	6	/	2
---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

5	-	6	/	2
---	---	---	---	---

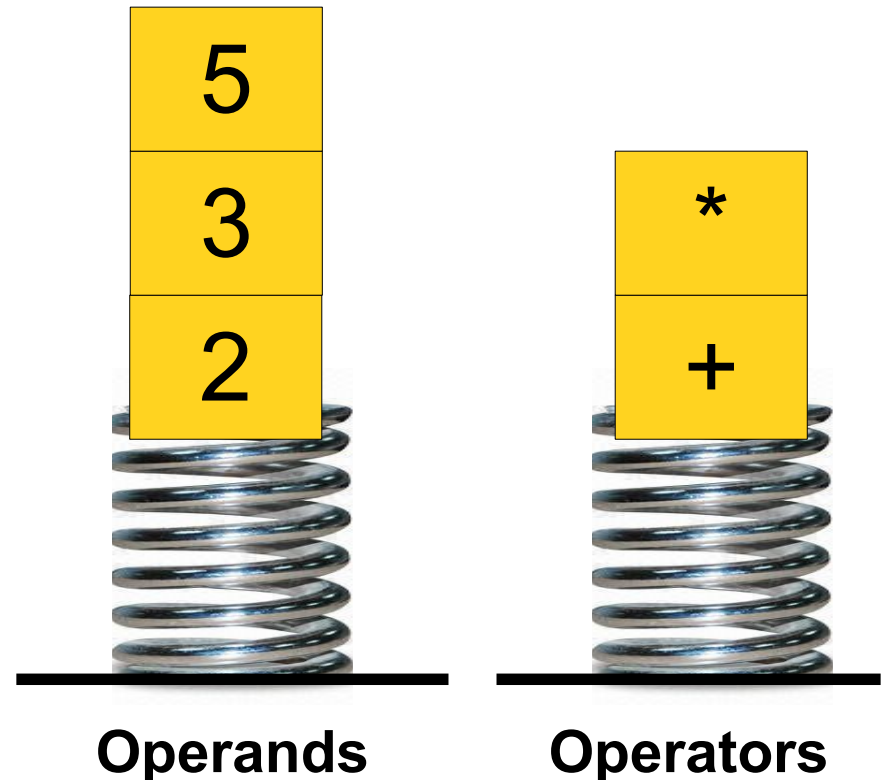




# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

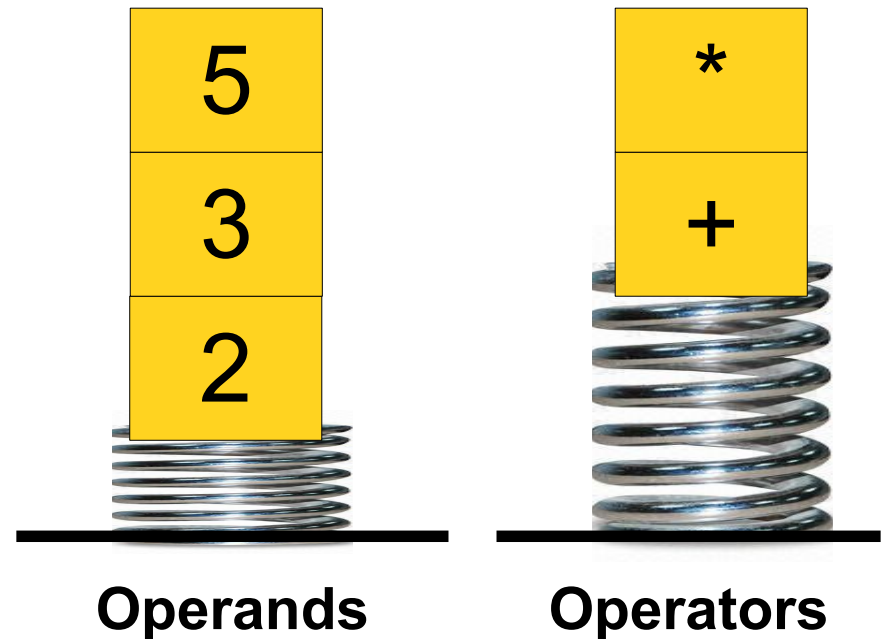
-	6	/	2
---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

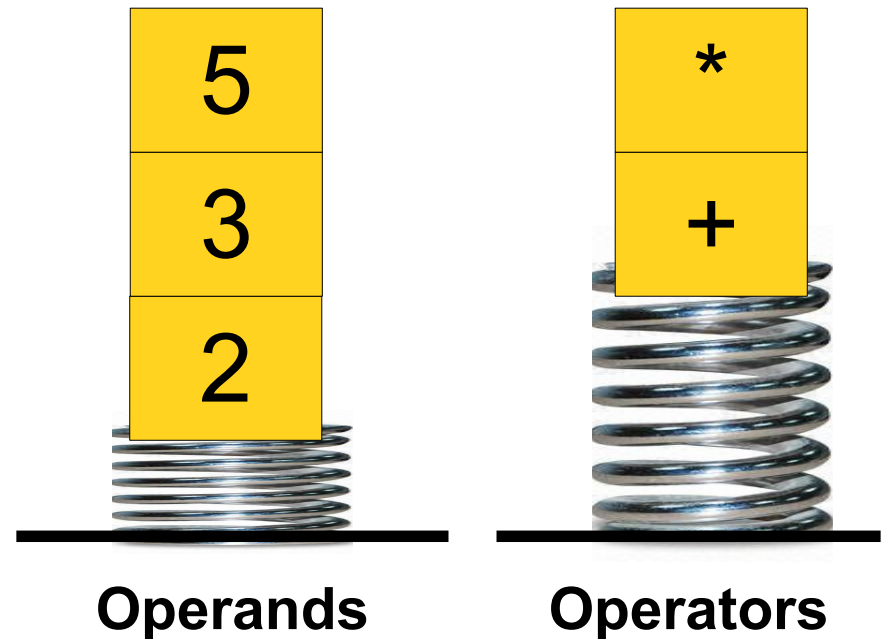
-	6	/	2
---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

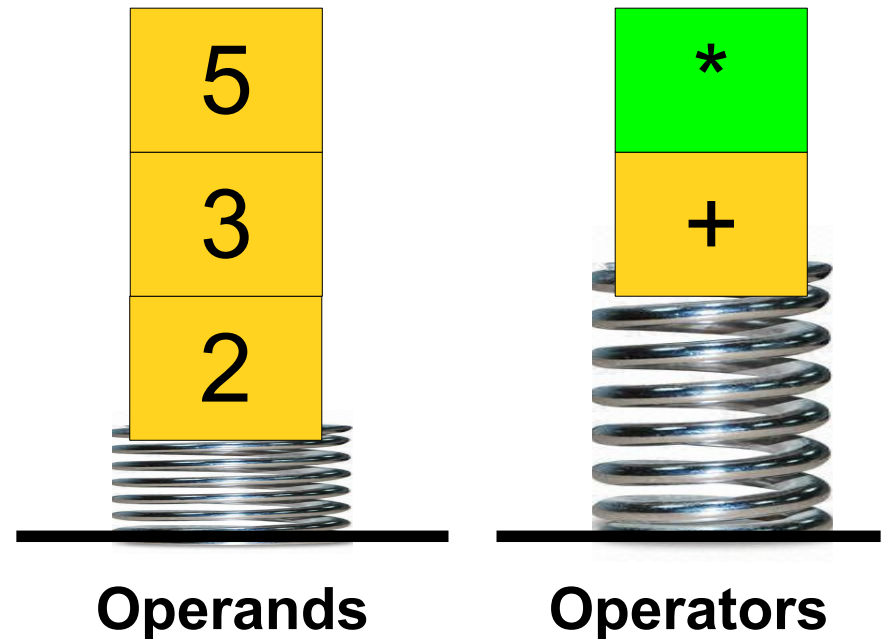
-	6	/	2
---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---

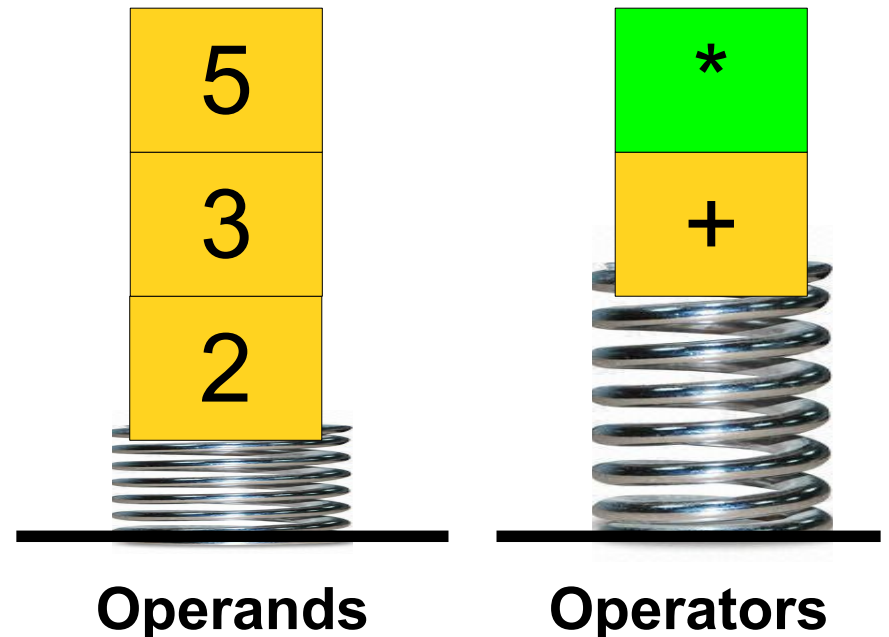


# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---

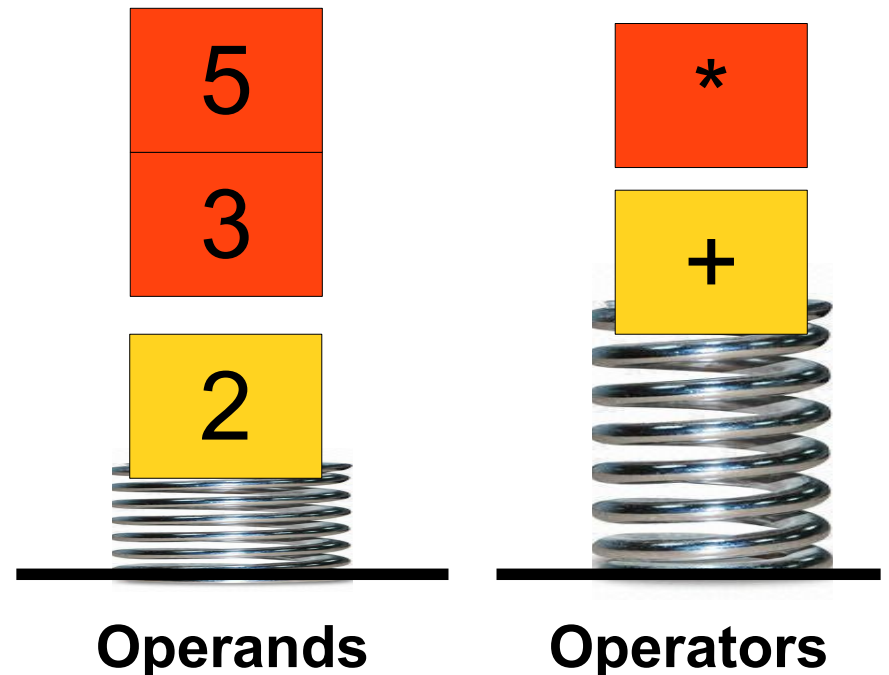
Subtraction has lower precedence than multiplication, so we need to evaluate the multiply before the subtract.



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---

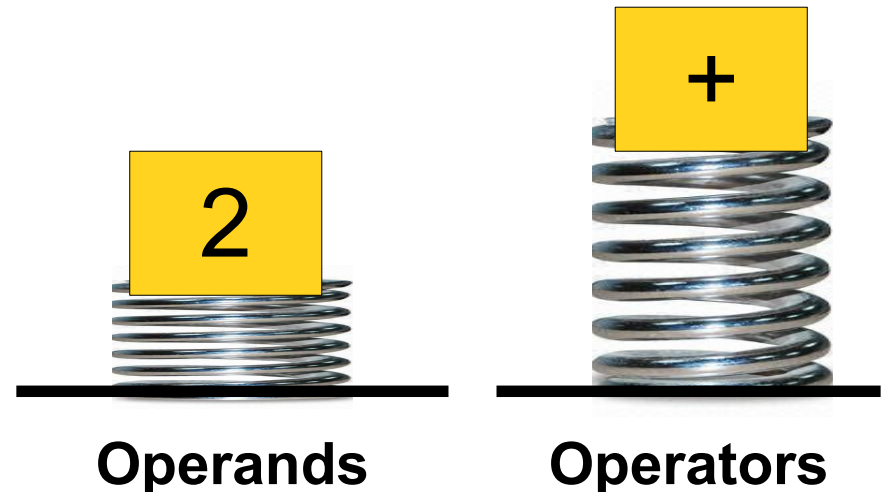


# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---

3	*	5
---	---	---

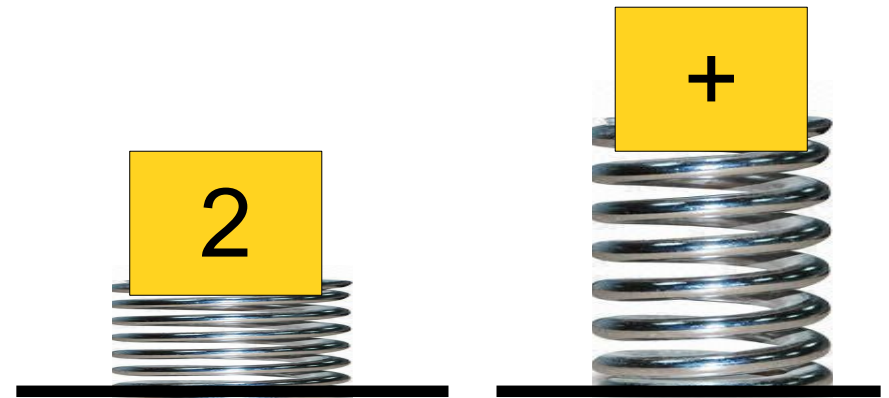


# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---

15
----



Operands

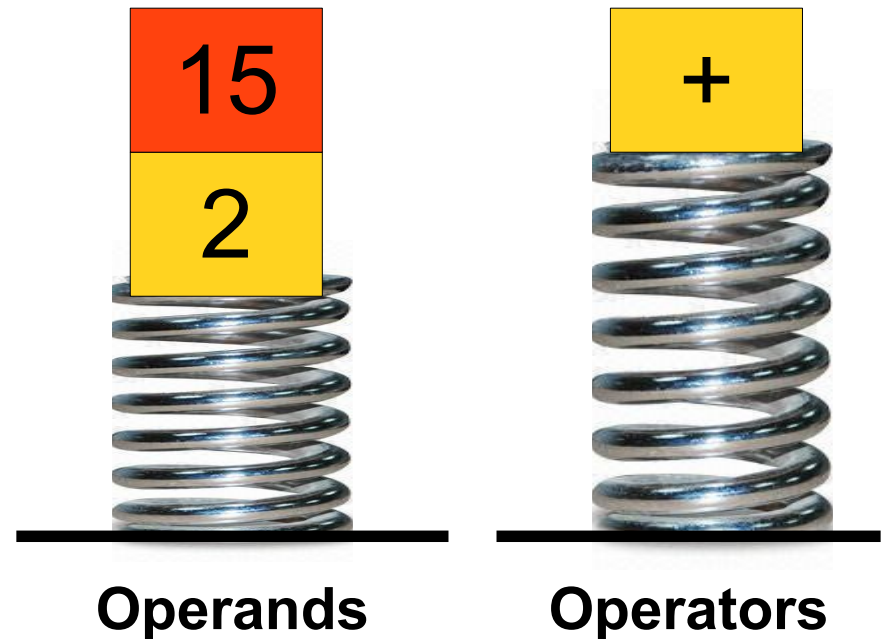
Operators



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

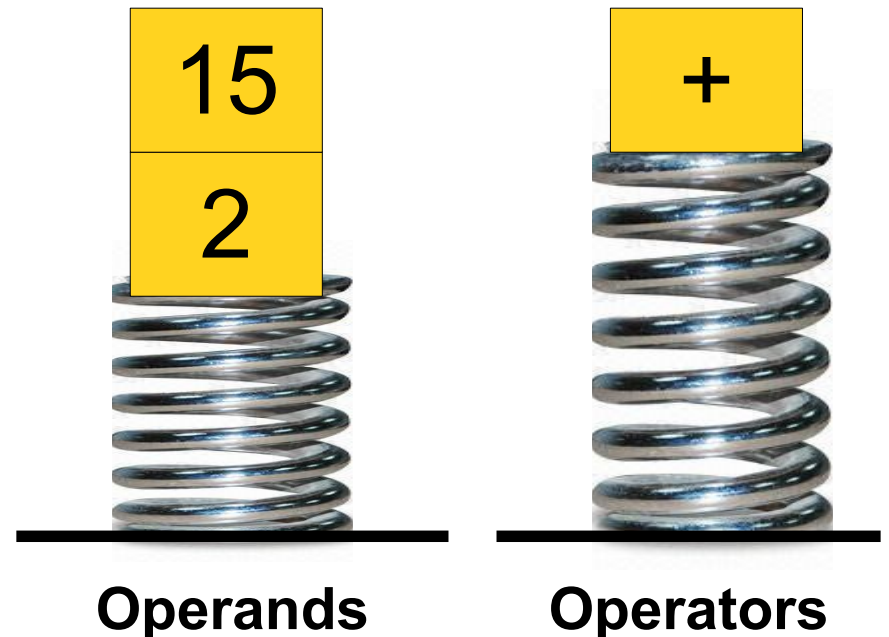
-	6	/	2
---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

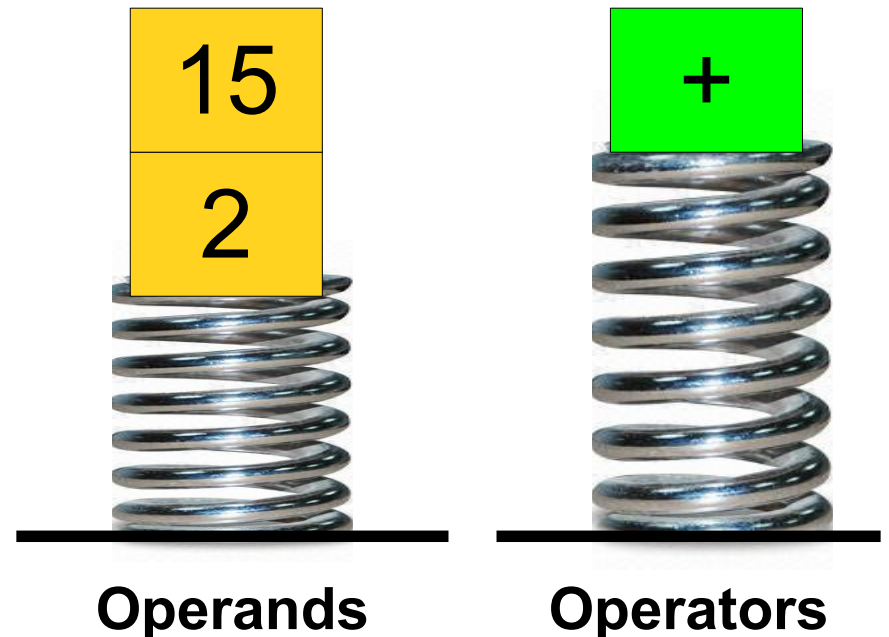
-	6	/	2
---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---

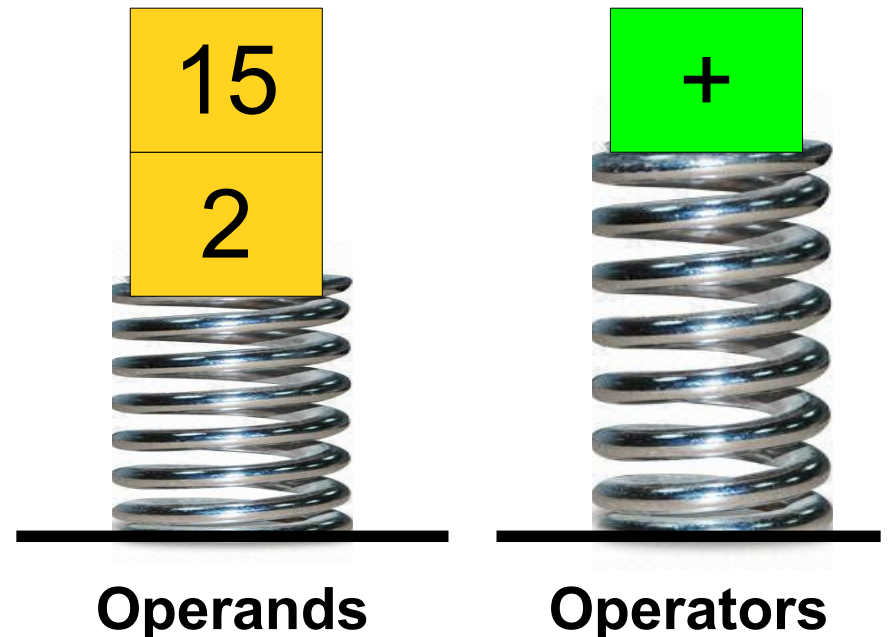


# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---

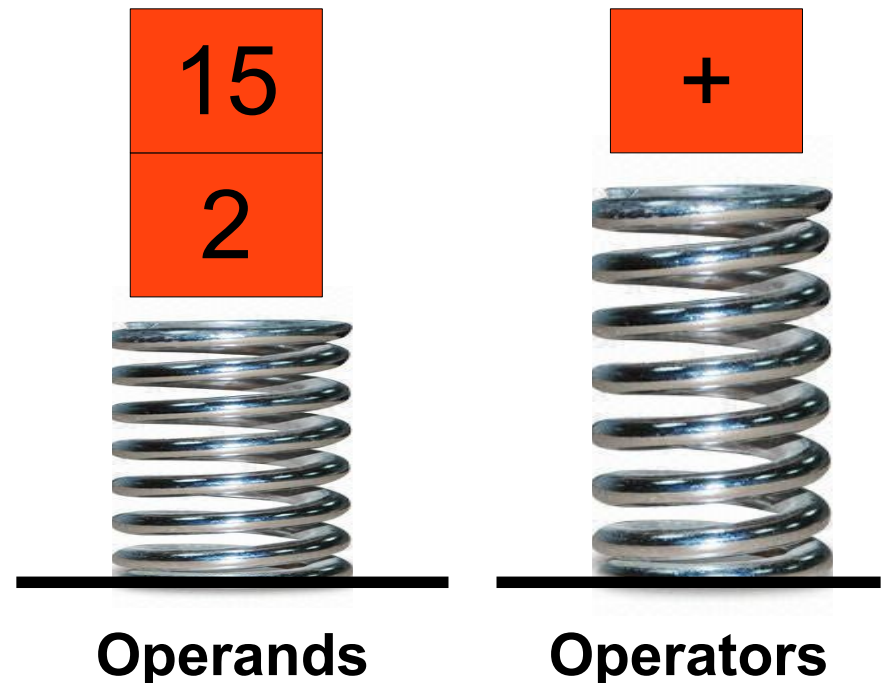
Subtraction has equal precedence to addition so we evaluate the add before the subtract.



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---

2	+	15
---	---	----



Operands



Operators

# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---

17
----



Operands

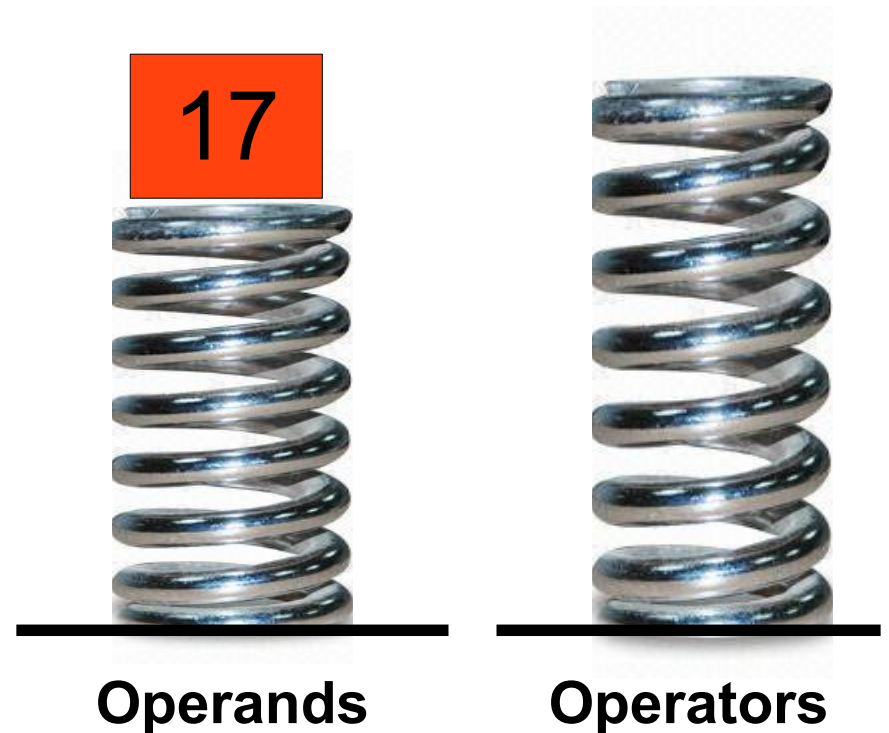


Operators

# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---





# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

-	6	/	2
---	---	---	---



Operands

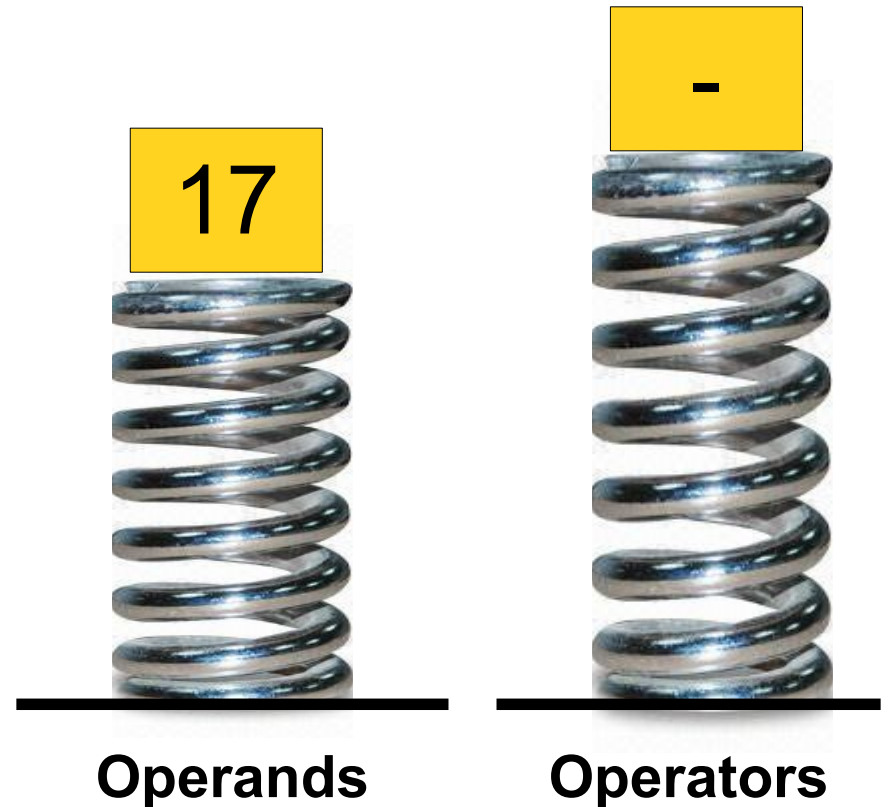


Operators

# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

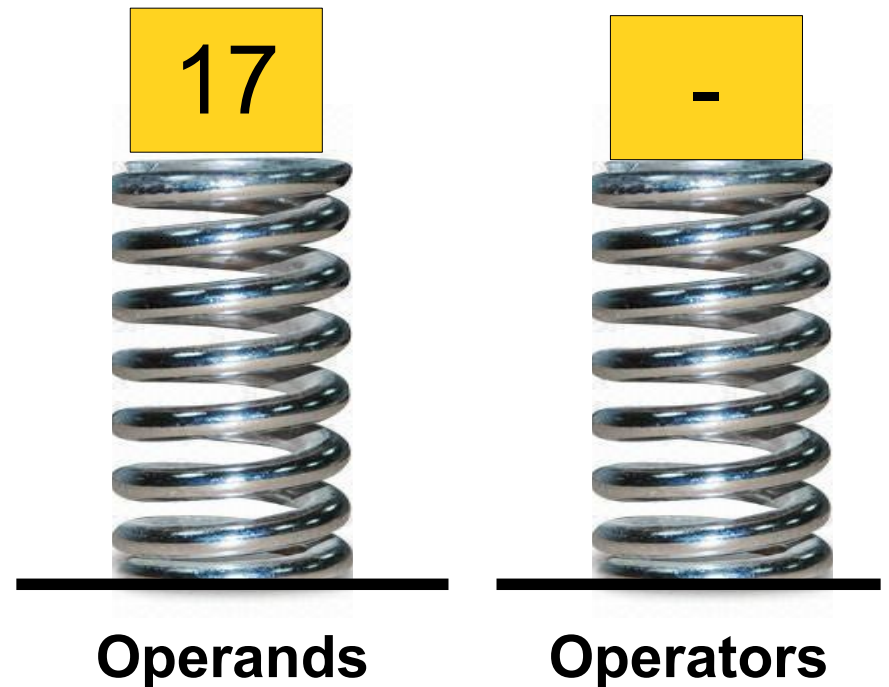
6	/	2
---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

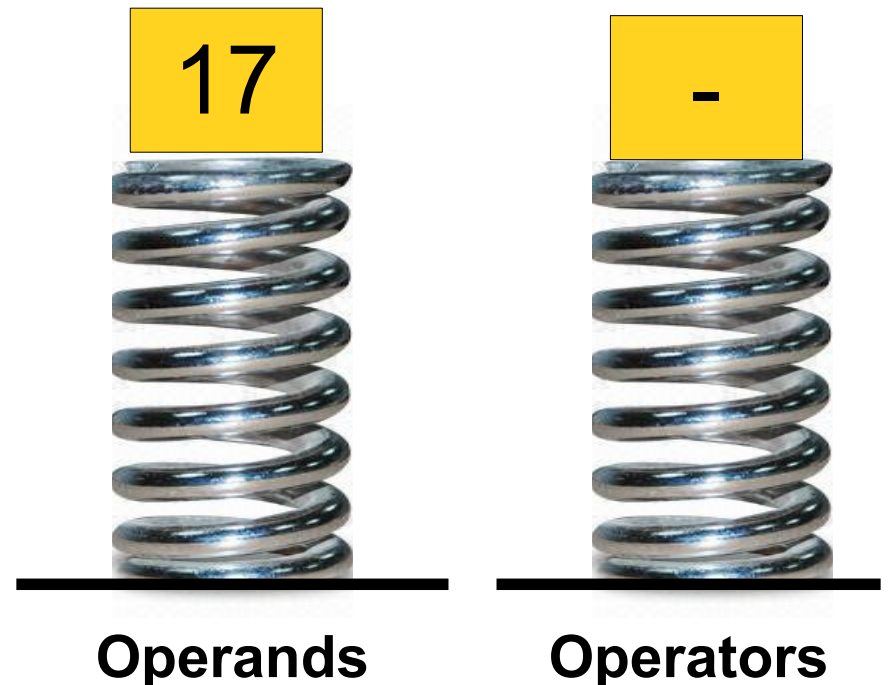
6	/	2
---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

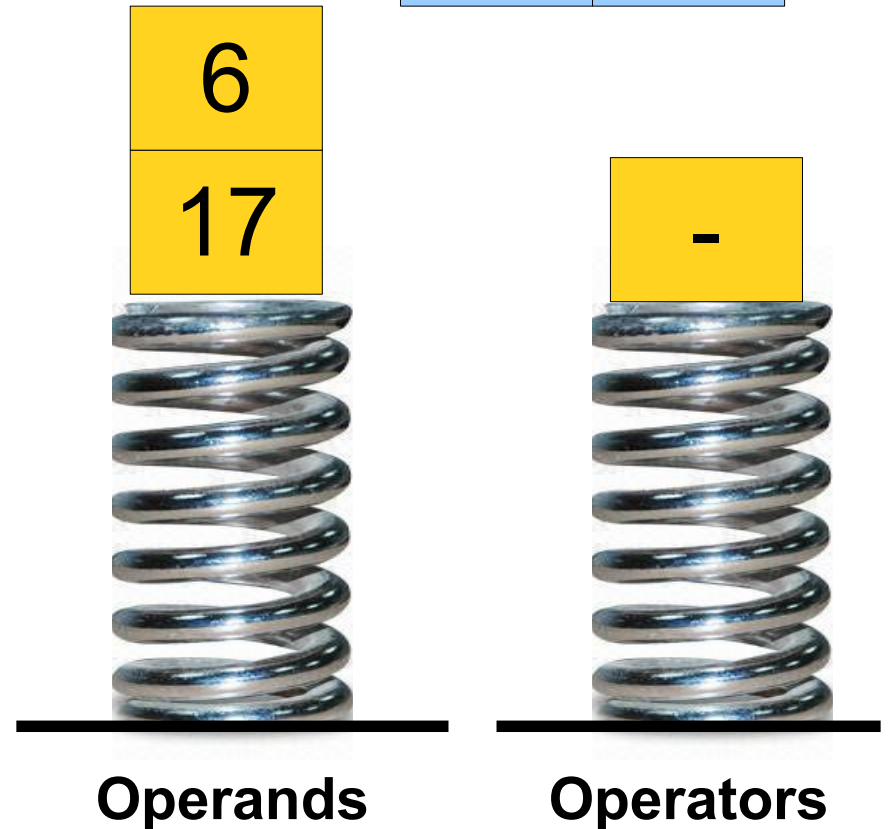
6	/	2
---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

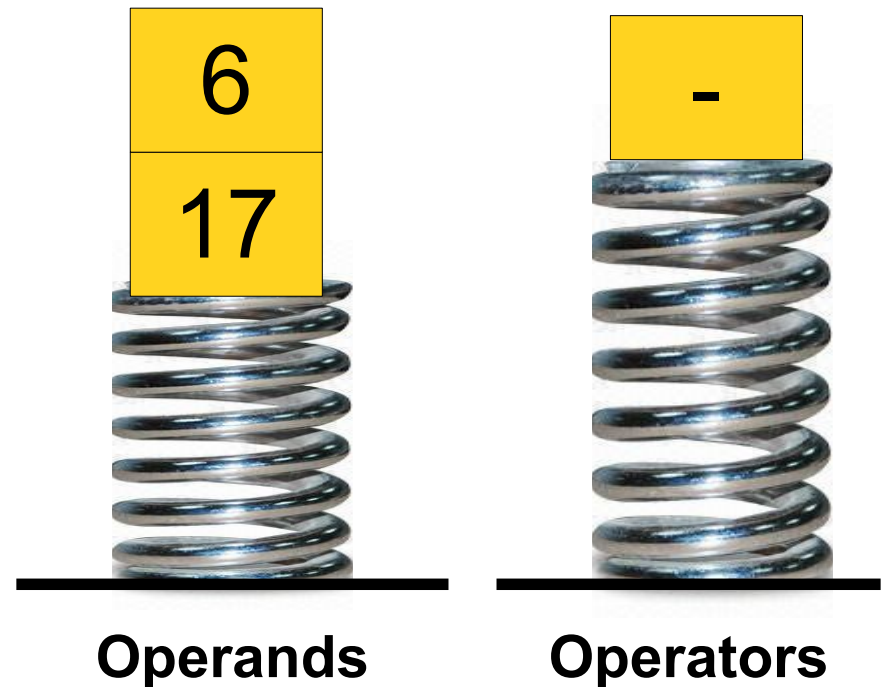
/	2
---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

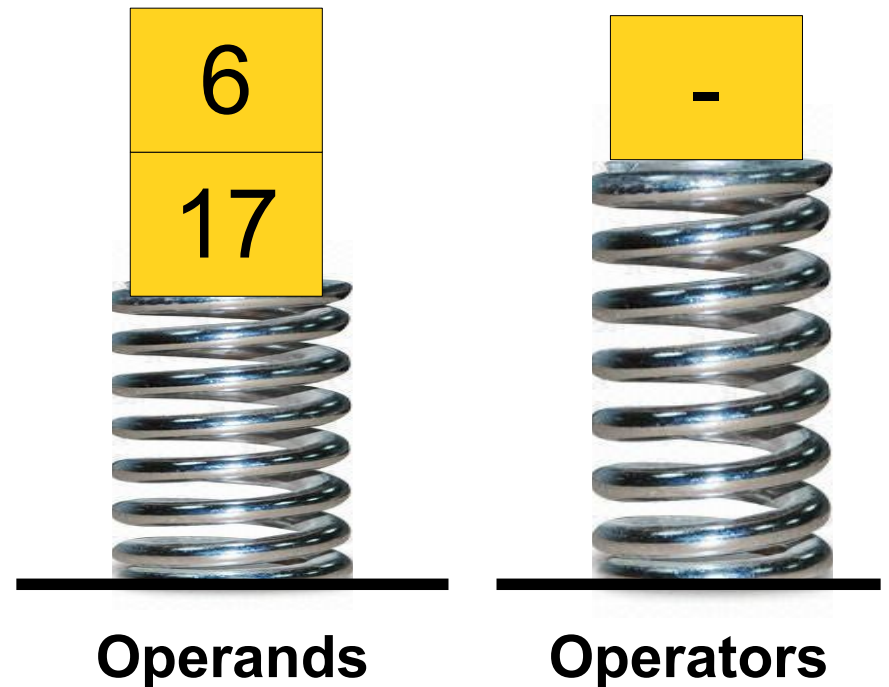
/	2
---	---



# The Shunting-Yard Algorithm

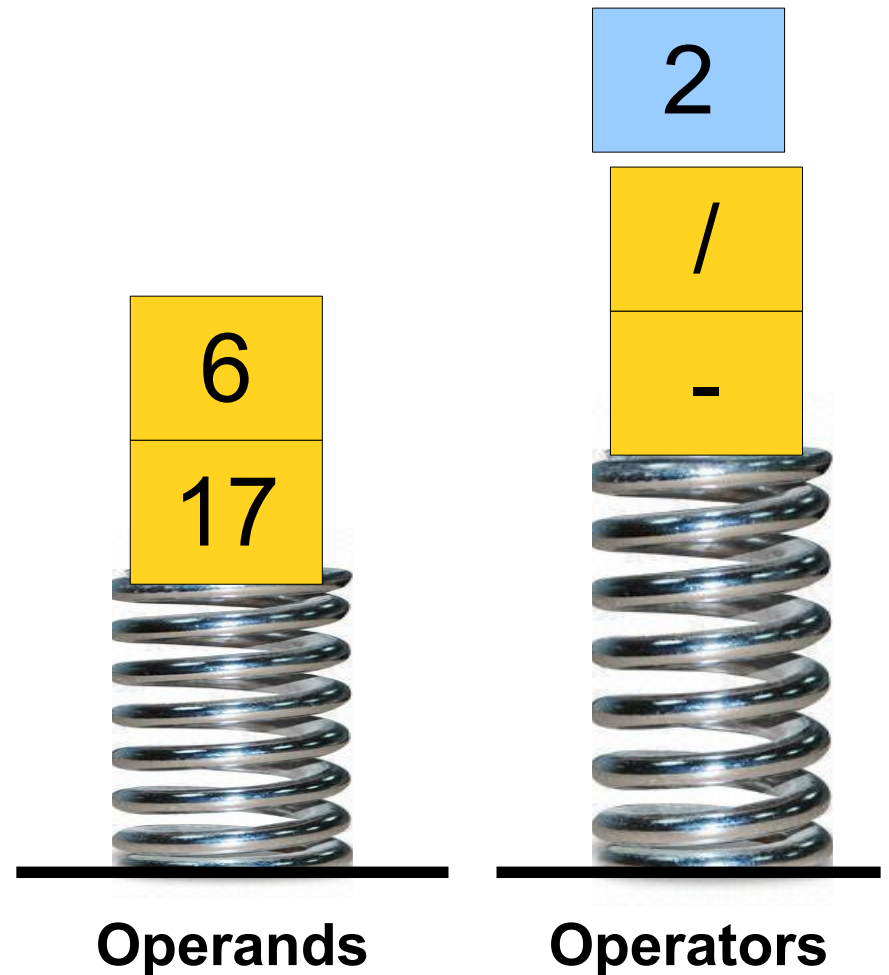
2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

/	2
---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

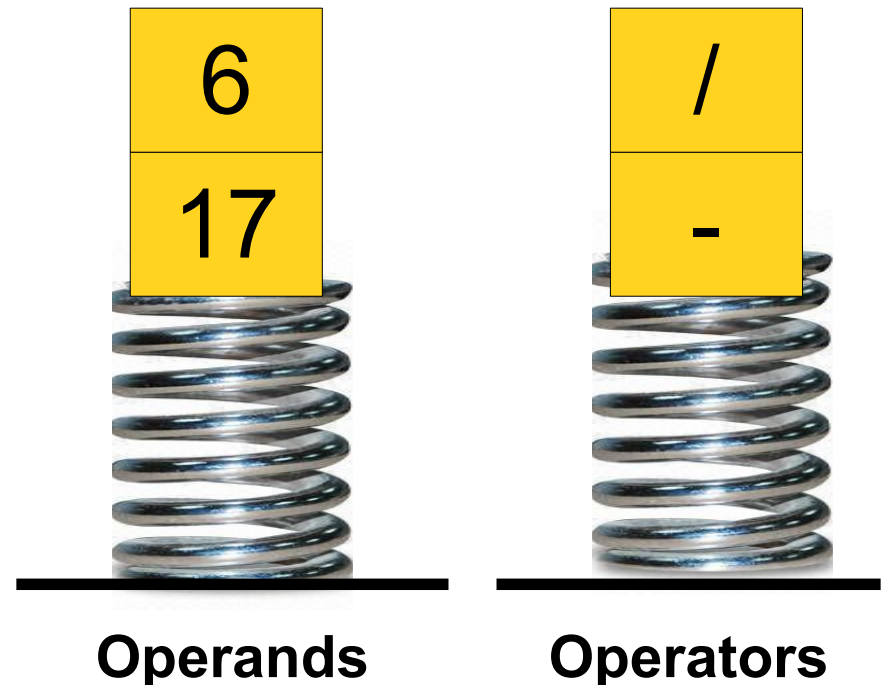




# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

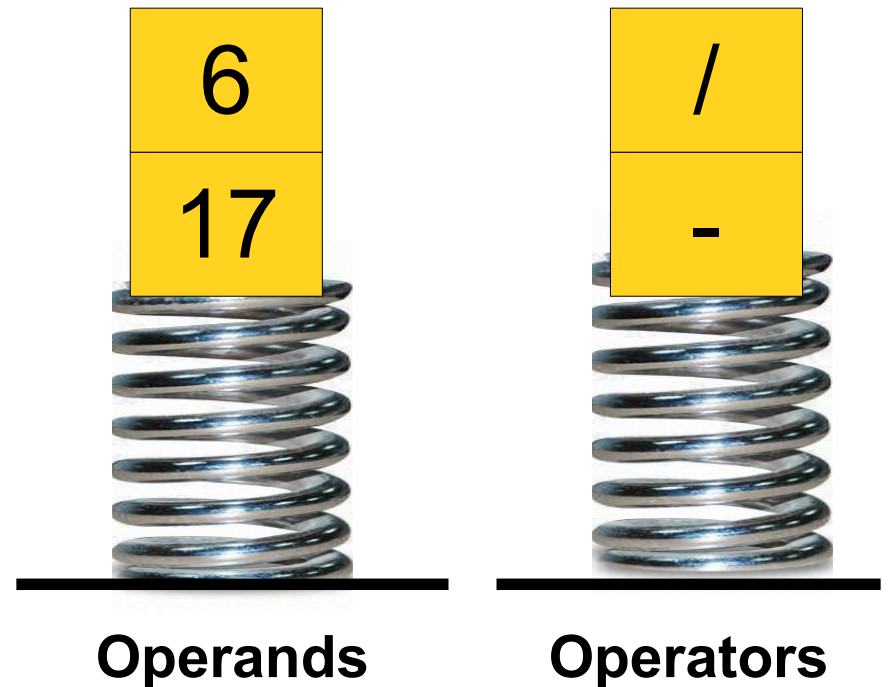
2
---



# The Shunting-Yard Algorithm

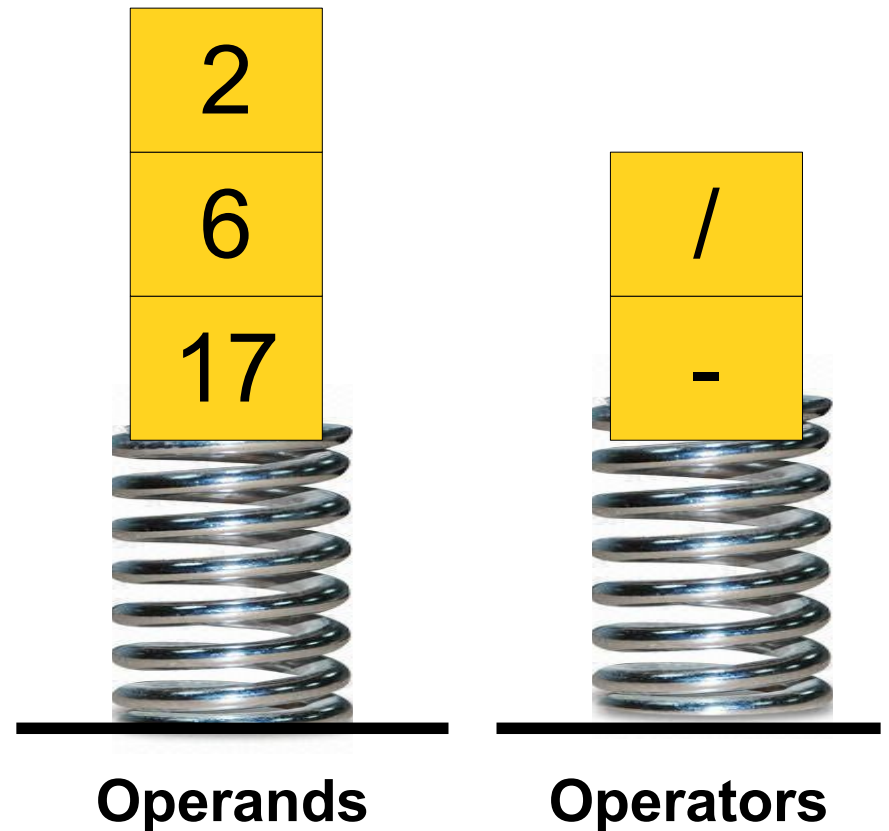
2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

2
---



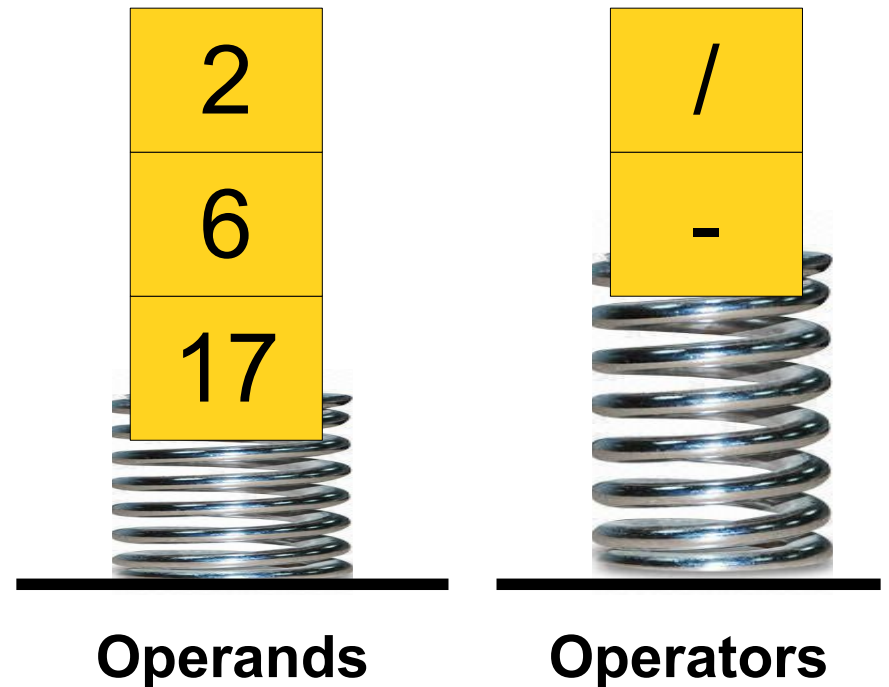
# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

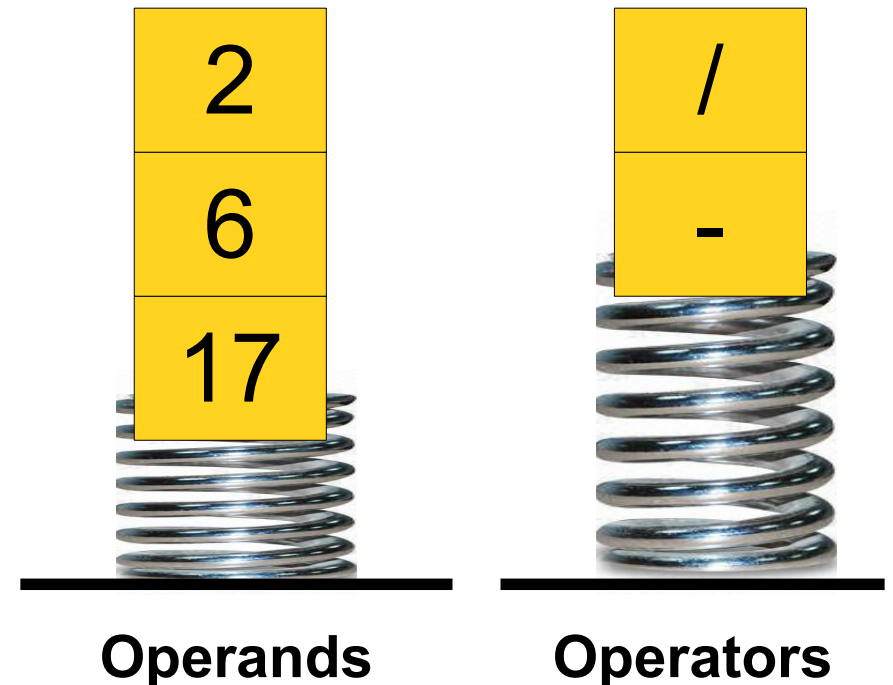
2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

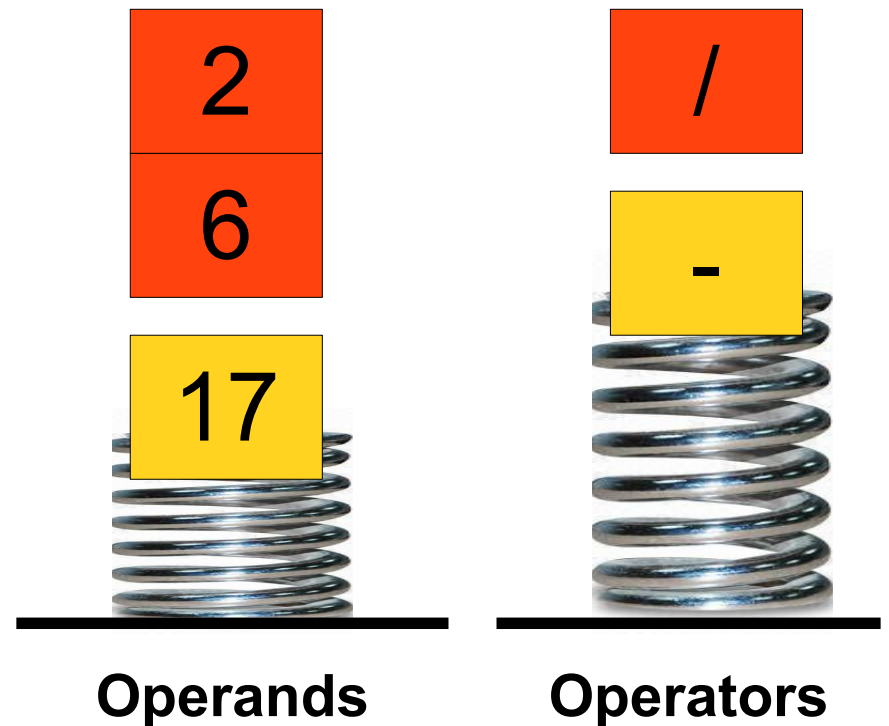
2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

Now that we've read all the tokens, we can finish evaluating all the expressions.



# The Shunting-Yard Algorithm

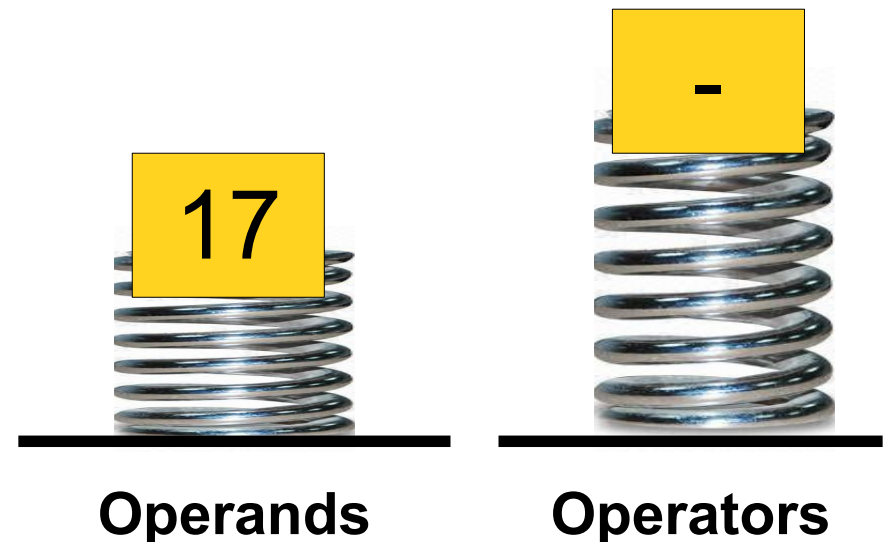
2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

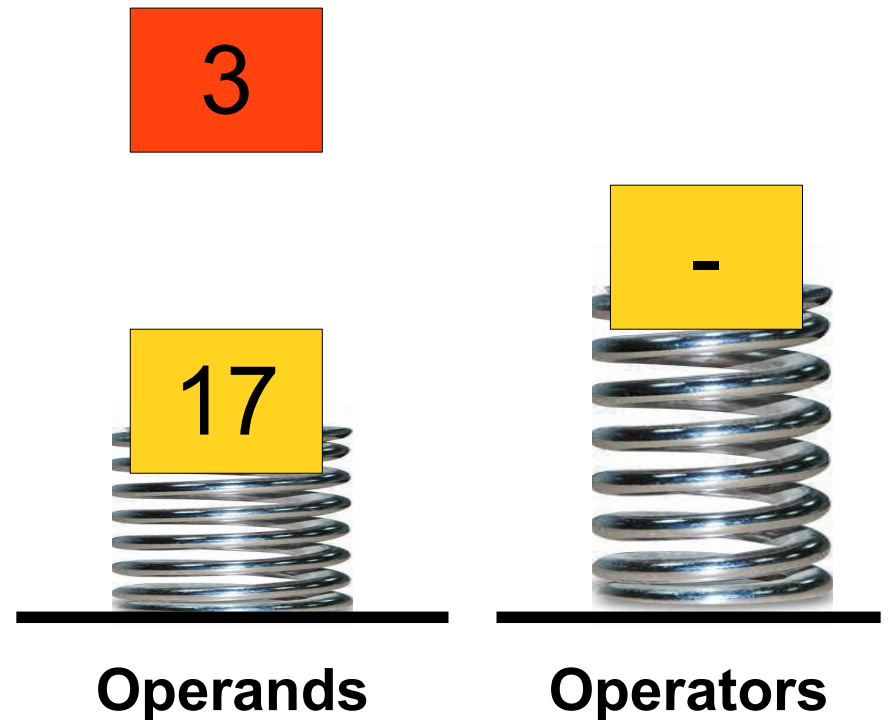
2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

6	/	2
---	---	---



# The Shunting-Yard Algorithm

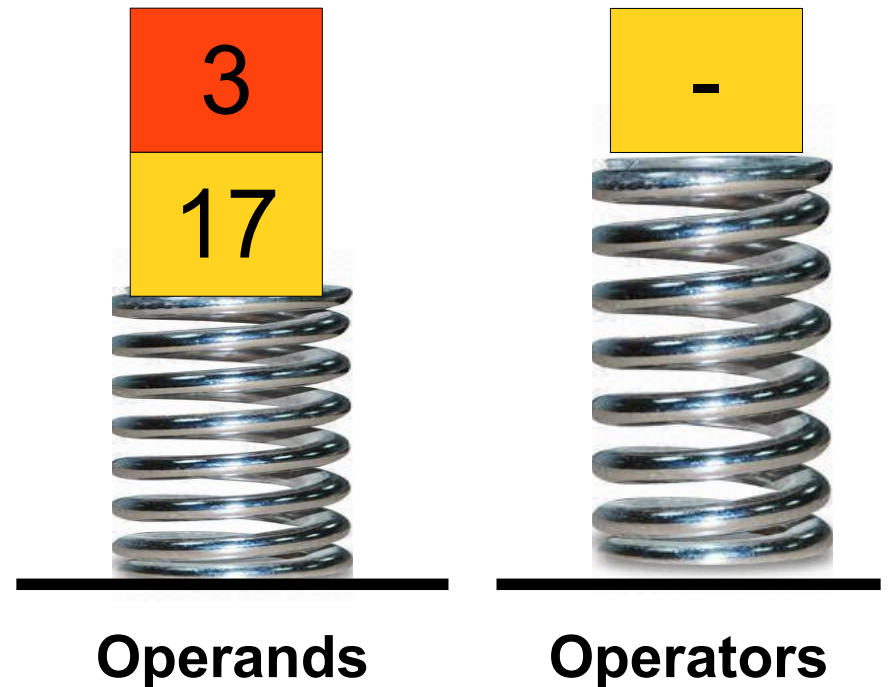
2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---





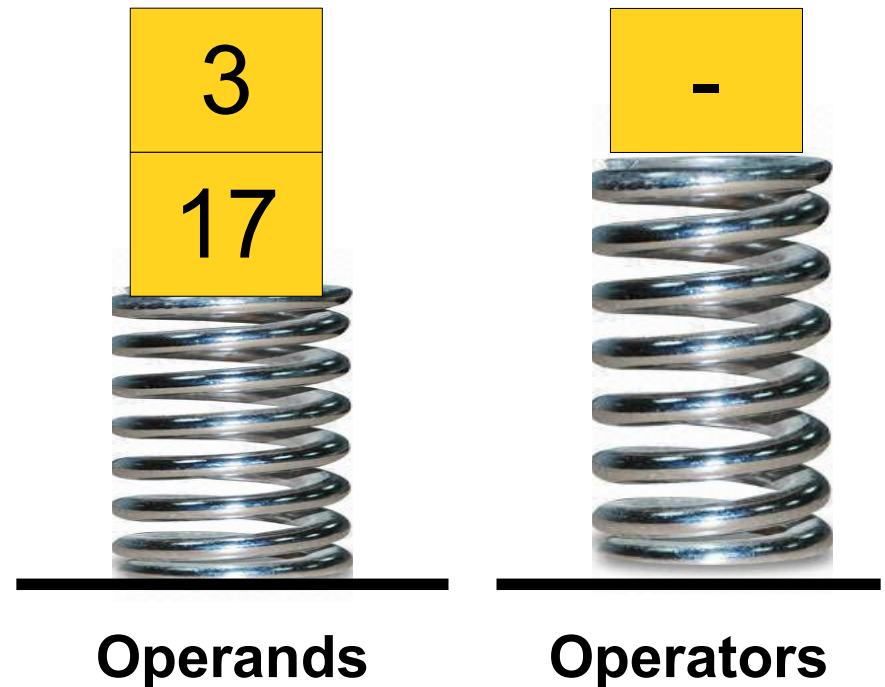
# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



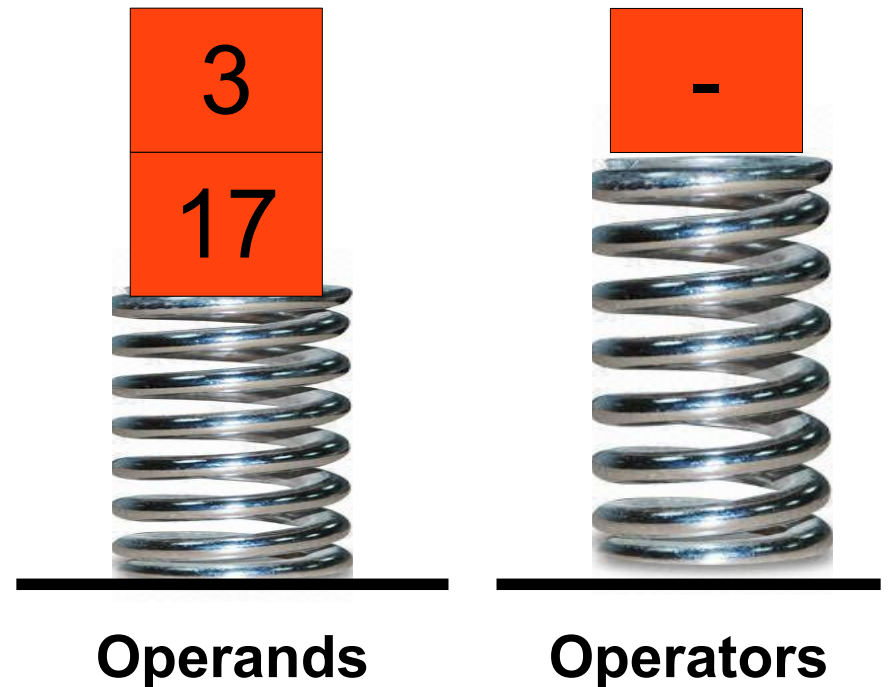
# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

17	-	3
----	---	---



**Operands**



**Operators**

# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---

14



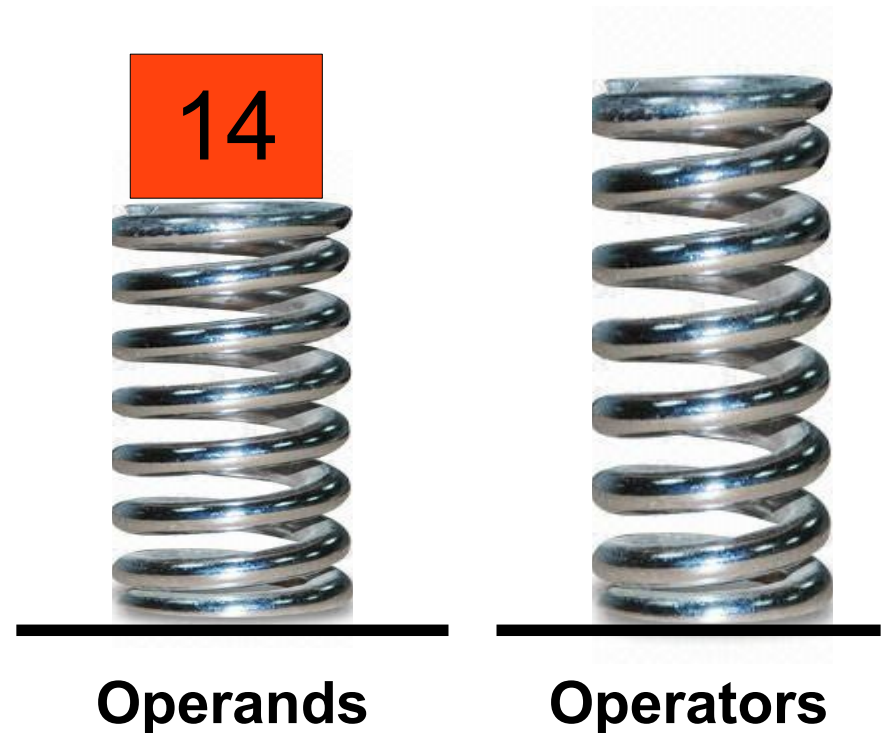
**Operands**



**Operators**

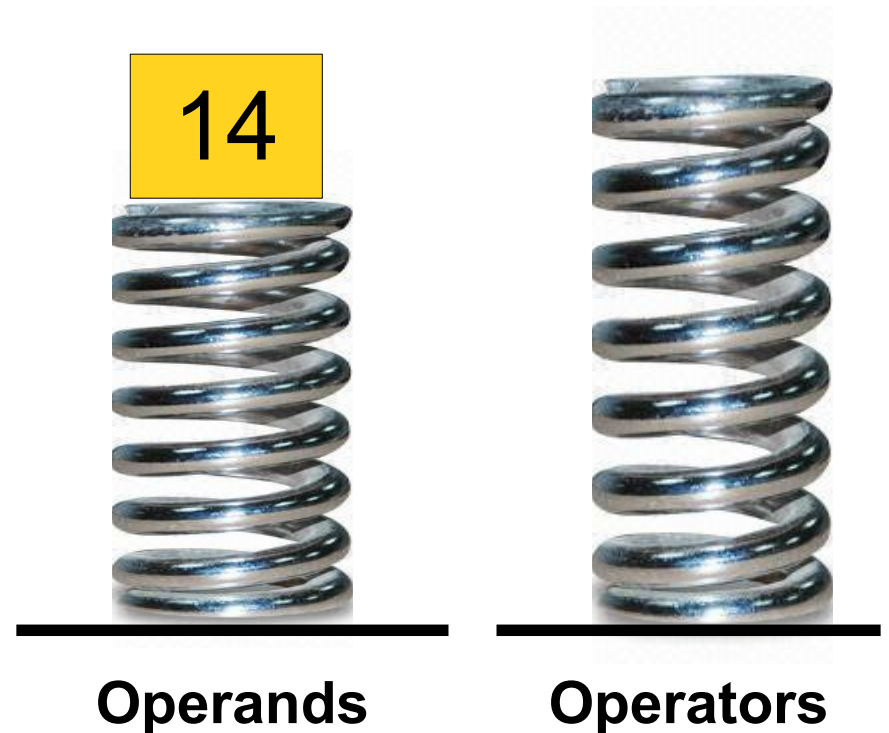
# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



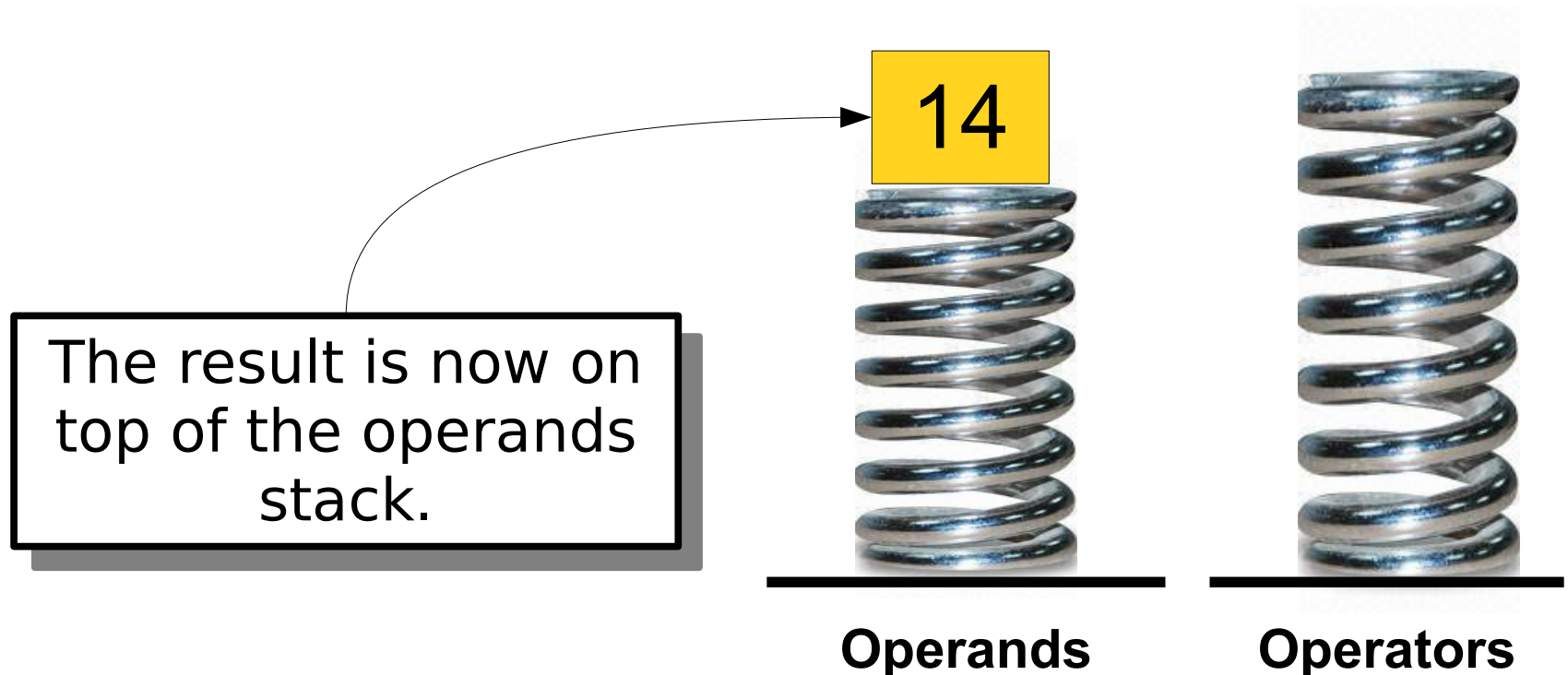
# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---



# The Shunting-Yard Algorithm

2	+	3	*	5	-	6	/	2
---	---	---	---	---	---	---	---	---





# The Shunting-Yard Algorithm

- Maintain a stack of operators and a stack of operands.
- For each token:
  - If it's a number, push it onto the operand stack.
  - If it's an operator:
    - Keep evaluating operands until the scanned operator has higher precedence than the most recent operator.
    - Push the operator onto the operator stack.
- Once all input is done, keep evaluating operators until no operators remain.
- The value on the operand stack is the overall result.

Pseudo-code(On Board)

shunting-yard.cpp (Computer)

# Extensions to Shunting-Yard

- How might you update the shunting-yard algorithm to:
  - Handle/report syntax errors in the input?
  - Support parentheses?
  - Support functions like sin, cos, and tan?
  - Support variables?

# Next Time

- **Vector**
  - A standard collection for sequences.
- **Grid**
  - A standard collection for 2D data.