Module 1: Types and Expressions

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Thanks to Alan Waldman
for comments that improved these slides

Prepared for 2u

Semester Online

Monolog 1

1.0 Introduction

- **What is a *type*?**
  - **A classification of items in the world based on**
    - The kinds of things an item can do
    - The
  - **integers, real numbers, character strings, …..**
- **As types, consider integers and real numbers**
  - **integer**
    - Useful for counting
    - Number of playing cards in a deck
  - **Real number**
    - Can include fractional values
    - Temperature readings and averages, interest rates
    - On the computer, we can only approximate real numbers
- **Data types in computer science**
  - **Represent values of interest**
  - **Allow operations that make sense**
- **Built in data types (in this module)**
  - **For representing integers, interest rates, names, addresses, facts**
- **Later, we design our own types**
  - **Bank account, hockey player, song**
- **The best choice of data type is not always obvious**
  - **Should you use an integer or a real number?**
  - **You might start with one, and change your mind later**
    - Height – might be integer number of centimeters
    - But if we're measuring something small, fractional values may be needed
- **There are rarely right or wrong choices**
  - **But a choice will have its advantages and disadvantages**
  - **Picking a suitable data type is an engineering process and is based on currently understood constraints and best planning for the future. The future can at times seem uncertain.**
  - **Example: Y2K**

End of Monologue

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  - How many words are in this sentence?

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- The above are 0 or positive, but negative values may be of interest as well

Oyster 2

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  - **How many exams will be given?**
  - **How many words are in this sentence?**
- **The above are 0 or positive, but negative values may be of interest as well**
  - **How many days until your 21st birthday?**
    - The week before, 7
    - The week after, -7
  - **How has the class size changed since yesterday?**
    - +5 students were added
    - -3 students dropped

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  - But how about the distance from Earth to Sun?

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- **These seem just fine for the quantities suggested thus far**
  - **But how about the distance from Earth to Sun?**
    - In meters: 149,597,870,700 Too big!
  - **We can represent values outside of the range of an `int` using techniques we learn later.**
  - **For now, we consider an `int` sufficient.**

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  - **But how about the distance from Earth to Sun?**
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  - **We can represent values outside of the range of an `int` using techniques we learn later.**
  - **For now, we consider an `int` sufficient.**
- **There are things we cannot represent conveniently with an `int`**
  - **Your name (need the alphabet, not just 0—9)**
  - **Your height in meters (need fractions)**
  - **Whether you are vegetarian or not**
- **We will see other data types soon that help us with those**

1.1 Our first data type: int

- **How do we represent a concept using the `int` data type? We do this by specifying:**
  - **The type of the concept (`int`)**
  - **A name for the concept (numStudents, numExams, etc.)**
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    - This value can change later, but it is important to have an *initial* value for the concept.

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int numStudents   = 390;
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- **There are conventions about how to pick *variable names*:**
  - **The first letter of the first word in a name begins with a lower-case letter**
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  - **There are no spaces (blanks) in a variable name**
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- **The name should be meaningful, clear, and relevant to the concept**

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- **Any valid expression can appear on the right-hand side**

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- **An assignment statement is evaluated as follows**
  - **The value of the right-hand side is computed (390 in this case)**
  - **The result is stored at the name declared on the left-hand side**

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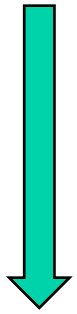

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  - **One after the other**
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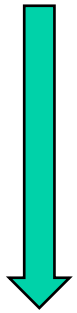

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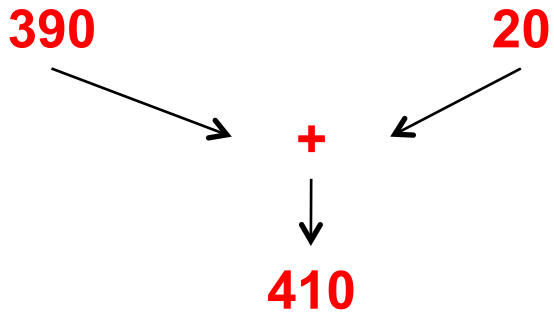

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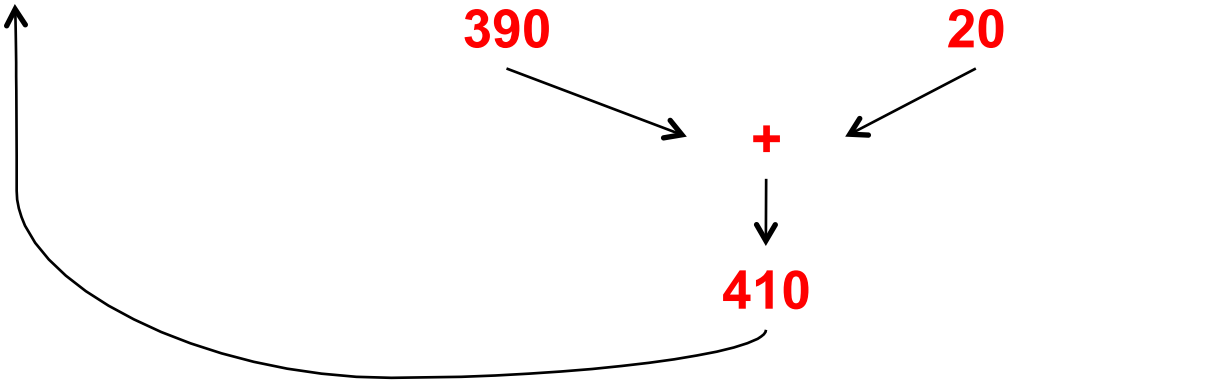

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Variable Name	Value
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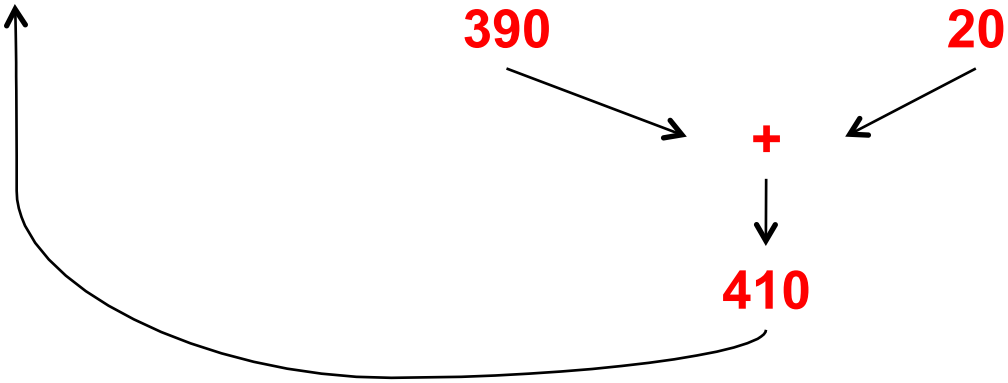

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Because we are assigning a previously-declared variable `numStudents` a new value, its type has already been declared as `int`, and we are not allowed to declare its type ever again

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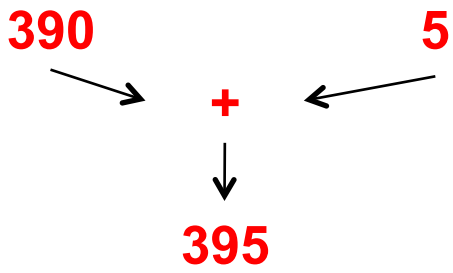

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numStudents	395
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```

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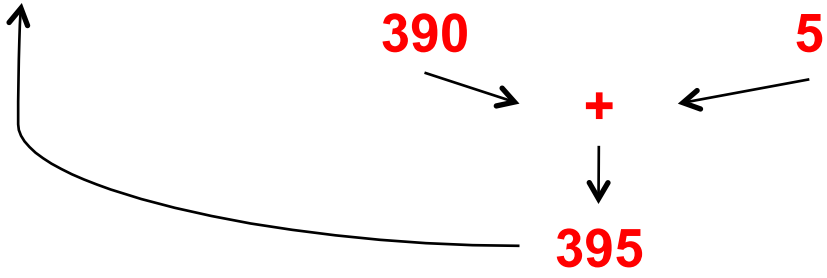

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numStudents = numStudents + 5;
```

- **Remember: we do *not* re-declare `numStudents`**
  - **It is already known to be an `int`**
  - **The new value simply replaces the old value**

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- **Other values are *not* automatically updated**
  - **They have only been assigned their initial value**
  - **Code executes from the top, reading down**

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```


End of Oyster

1.1b Exercise

- **Video intro**
  - **Important to try things out in small doses**
  - **Story**
    - Alice has 7 carrots
    - Bob has 3 more than Alice
    - Charles has 4 times as many as Alice
    - Also, Charles stole all of Bob's carrots
    - Diane has twice as many as Charles
- **Question card: Translate the story to code**
  - **Print out how many Diane has at the end**
    - `System.out.println(dianeCarrots);`
- **Response: go over my solution**

Roundtable

1.1c Now get input from the user

- Student asks question about how to make Alice's carrots a value input by the user
  - Much more on this later
  - But for now we use the `ArgsProcessor` stuff
- Show what happens when we try to use it
  - import the right thing with eclipse's help
- Meaningful prompting messages
- Run it a few times

End of Roundtable

Oyster 3

1.2 Operations on `int` types

- **Most operations work as expected**
  - **+ plus**
  - **- minus**
  - *** times**
- **One operation usually surprises students and experienced programmers alike**
  - **Division using the / operator**
  - **Returns an `int`, so no fractional values are allowed**
  - **The value returned is as if the digits past the decimal point were dropped**

Expression	Value
`4 / 2`	2

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Expression	Value
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`3 / 2`	1

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Expression	Value
`4 / 2`	2
`3 / 2`	1
`5 / 2`	2

1.2 Operations on `int` types

- **Most operations work as expected**
  - **+ plus**
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- **One operation usually surprises students and experienced programmers alike**
  - **Division using the / operator**
  - **Returns an `int`, so no fractional values are allowed**
  - **The value returned is as if the digits past the decimal point were dropped**
  - **We are not allowed to divide by 0**

Expression	Value
4 / 2	2
3 / 2	1
5 / 2	2
7 / 0	Error !

1.2 Operations on `int` types

- **The % operator computes the remainder after division**

x	y	x / y	x % y
4	2	2	0

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5	2	2	1

Why is this useful?

1.2 Operations on `int` types

- The % operator computes the remainder after division
- Examples:
  - Convert a large number of pennies into dollars and cents

```
int pennies = 789321;
```

Variable Name	Value
pennies	789321

1.2 Operations on `int` types

- The % operator computes the remainder after division
- Examples:
  - Convert a large number of pennies into dollars and cents

```
int pennies = 789321;

int dollars = pennies / 100;
```

Variable Name	Value
pennies	789321
dollars	7893

1.2 Operations on `int` types

- The % operator computes the remainder after division
- Examples:
  - Convert a large number of pennies into dollars and cents

```
int pennies = 789321;

int dollars = pennies / 100;

int cents   = pennies % 100;
```

Variable Name	Value
pennies	789321
dollars	7893
cents	21

End of Oyster

1.3 Exercise

- **Video intro**
  - **We see how to take a number of pennies and compute the dollars and cents contained therein**
  - **First we'll write code for that much and make sure it works.**
  - **Then we will incrementally improve the code**
    - Allow quarters in change
    - Allow nickels and dimes too

1.3 Exercise

- **Question card**
  - **Write code that gives change as follows:**
    - Prompt the user for a number of pennies
      - Call this value `initialPennies`
    - Compute d as the number of dollars contained therein
      - Let's assume the user trades in the appropriate number of pennies for the `d` dollars
    - Compute `penniesLeftAfterDollars` as the number of pennies that remain
    - Print out the dollars and cents that are contained in the `initialPennies`
  - **Try out your code and make sure that it works**

1.3 Exercise

- **Question card**
  - **Now improve your code so that quarters can be given as well**
    - Assume `penniesLeftAfterDollars` remain after dollars are given
    - How many quarters could be substituted for that many pennies? Call this value `q` and print it out as well as the pennies left over after dollars and quarters are exchanged
- **Example: 798 pennies**
  - **7 dollars, leaving 98 penniesAfterCollars**
  - **q=3 quarters in 98 pennies**
  - **23 pennies left over**

1.3 Exercise

- **Question card**
  - **Now improve your code so that change can be made**
    - dollars
    - quarters
    - dimes
    - nickels
    - pennies left over

1.3 Exercise

- **Example**
  - **798 pennies initially**
  - **Should get**
    - 7 dollars, leaving 98 cents
    - 3 quarters, leaving 98-75 = 98 % 25 = 23 cents
    - 2 dimes, leaving 3 cents
    - 0 nickels
    - 3 pennies

1.3 Exercise

- **Video response**
  - **Goes over a correct solution line by line using the example from the setup**
  - **How would we verify that the answer we produced was correct?**
    - `d*100 + q*25 + d*10 + n*5 + p` should equal `initialPennies`

End of BLT

Roundtable

- **Conversation about implementation of math on computers**
  - **If we have the largest integer value and add 1 to it, what happens?**
    - Show this with screenflow movie
- **We see computers of all sizes**
  - **Desktops, laptops, cell phones, smart watches**
  - **The basic hardware mechanisms of those computers can perform arithmetic differently**
    - Largest and smallest values
- **Java requires all computers to perform arithmetic Java's way**
  - **Because of Internet applets**
  - **A Java program runs the same way anywhere**
  - **Widespread portability and software reliability**

End of Roundtable

Oyster 5

1.4 Building Bigger Expressions

- **We can combine smaller expressions into bigger**
  - **Using operators between smaller expressions**
  - **Using parentheses**
    - To direct the order of evaluation
    - To improve the clarity of the expression
- **My Dear Aunt Sally**
  - **Multiplication and Division have higher precedence**
  - **Addition and Subtraction have lower precedence**
  - **Evaluation is otherwise left-to-right**
  - **Parenthesized expressions have highest precedence**

1.4 Building Bigger Expressions

Expression	Value	Notes
`3 + 4`	7	As expected

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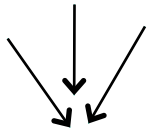
`4-3-2-1`	`-2`	Should you use parentheses here to make this clearer?
`4-(3-(2-1))`	`2`	To get this result, parentheses are necessary

1.4 Building Bigger Expressions

- To understand how an expression is computed, we draw its *evaluation tree*
- Evaluation proceeds from the leaves of the tree toward its root
- A node can be computed only when the values from all of its children are available

```
int val = (2 + 3) / 2;
```



```
5
```

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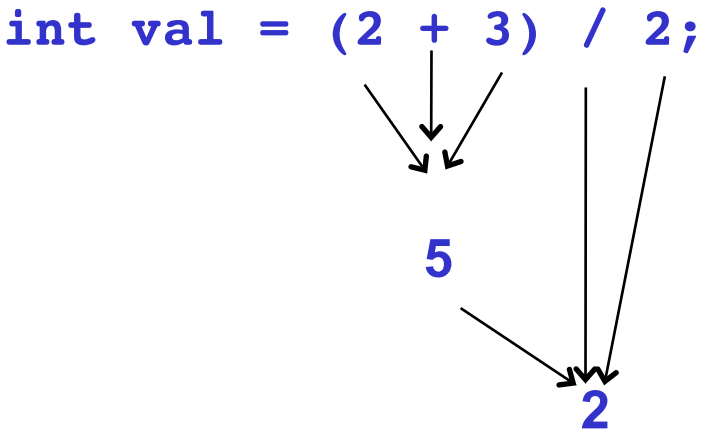
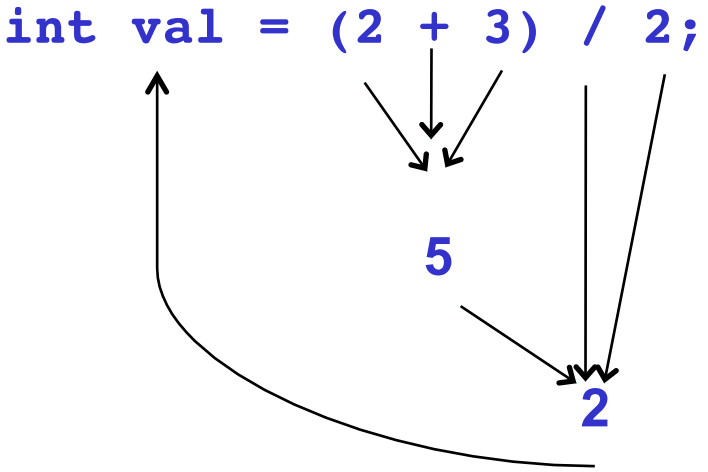


1.4 Building Bigger Expressions

- To understand how an expression is computed, we draw its *evaluation tree*
- Evaluation proceeds from the leaves of the tree toward its root
- A node can be computed only when the values from all of its children are available
- Expression is complete, and value is stored



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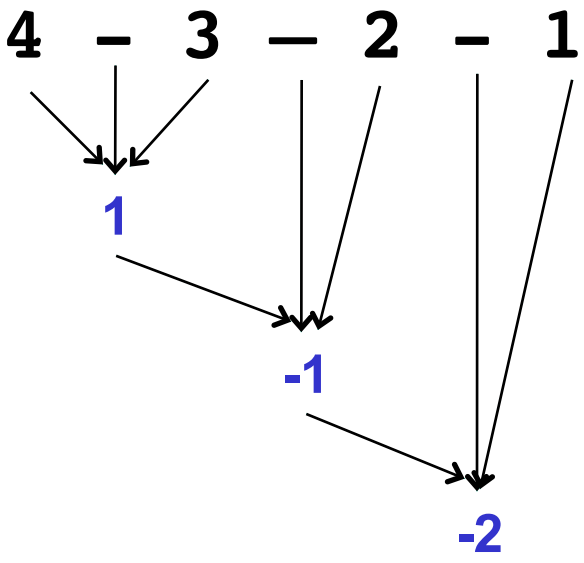

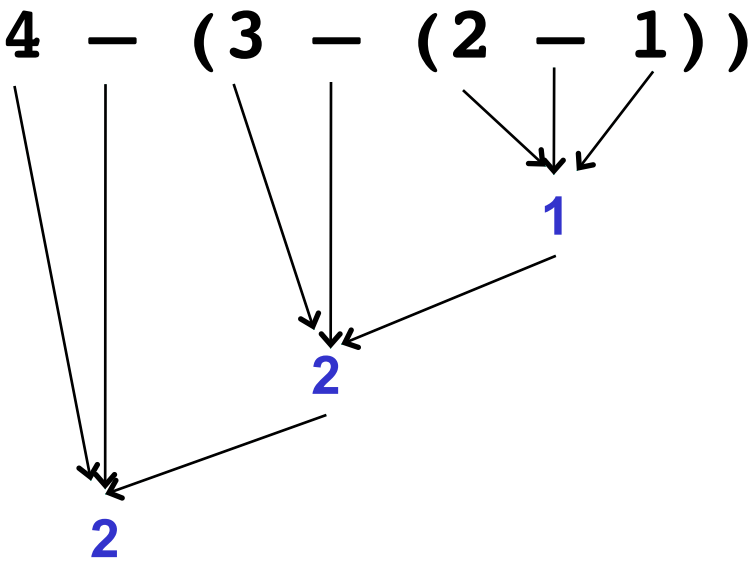

1.4 Building Bigger Expressions

- These large and complicated expressions are truly pedagogical examples
- We write programs not only for the computer
  - But for other humans to understand
- The computer has no problem with large, complicated expressions
  - But we humans do!
- Better to write simpler, easier-to-read expressions
  - If it takes you time to understand what you wrote, then what you write is too complicated
  - A good test is to show a friend your code and get critical feedback about its quality and readability

End of Oyster

1.5 The `double` data type

- The `int` data type allows us to represent integer-valued items
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  - How many exams will be given?
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  - How many words are in this sentence?
- We sometimes need value beyond the decimal point
  - The average age of students in this class
  - The probability of “heads” on a coin flip
- We sometimes need really large or small values
  - 6.0221413×10^{23} (Avagadro’s number)
  - 3×10^{-9} seconds (Time for light to travel one meter)

1.5 The `double` data type

- **The syntax is similar**
  - **The type is different (`double`)**
    - This is an unfortunate choice of name for a type
      - It refers to the amount of space used on a computer to represent the type.
    - We should think of it as a type that represents *rational* or *real* numbers

```
double secsPerMeter = .000000003;
```

1.5 The `double` data type

- **The syntax is similar**
  - **The type is different (`double`)**
  - **We can use scientific notation**
    - The E character represents “times 10 to the”
    - You can also specify the E as lower-case e

```
double  secsPerMeter = 3E-9;
```

1.5 The `double` data type

- **Most operations work as expected**
  - **+ plus**
  - **- minus**
  - *** times**
- **As with `int`, division has some quirks for `double`**
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  - **The data type is inexact for some values**
  - **For nonrationals there is nothing we can do about this**
    - How would you represent “pi” exactly?
  - **For rationals, we can design a better data type**
    - But the fastest arithmetic on the computer is approximate in terms of values, as shown below
- **All of this is governed by an accepted standard**
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  - **Maximum and minimum**
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  - **Constants**
    - `Math.PI` – closer to the actual value of π than any other `double`
    - `Math.E` – closer to the actual value of *e* than any other `double`
- **Many, many more. See this link**

End of Oyster

Roundtable

- Randomness
  - Run the random number generator and observe some of its outputs
  - Compute the average of 10 such numbers
- Pseudo-random
  - What does this mean?

End of Roundtable

1.6 Mixed-type Expressions

- **We can combine types in expressions where this makes sense**
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  - **Here we look at `int` and `double` types**
- **If two types participate in an expression**
  - **The result is usually of the more general type**
- **The `double` type is more general than the `int` type**
  - **We can represent any `int` as a `double`**
    - For example, `3` becomes `3.0`
  - **But the converse is not true**
    - No way to represent 0.5 as an `int`

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- **To understand how an expression is computed, we can draw its *evaluation tree***

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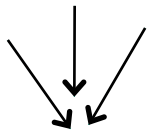

5

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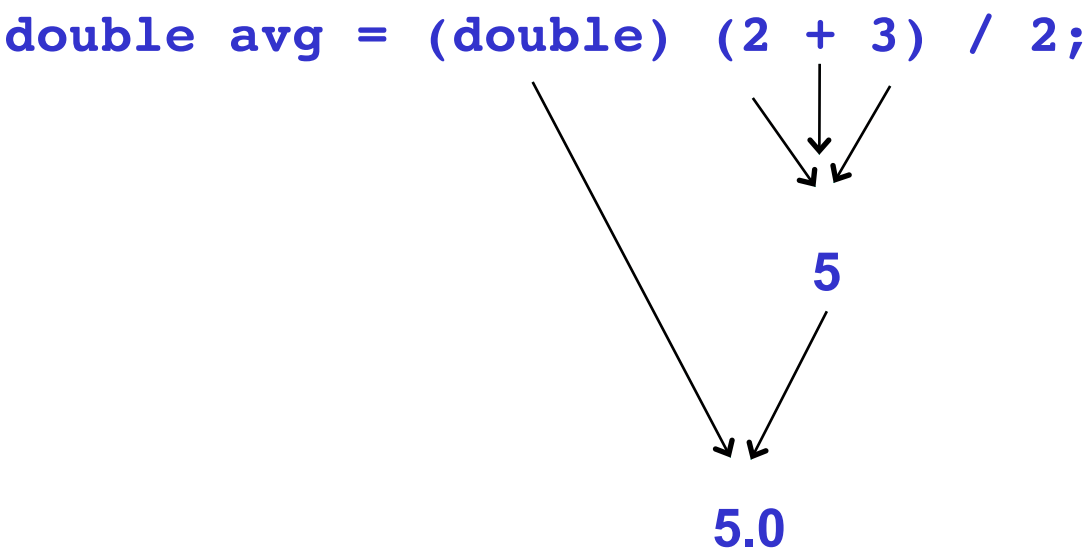

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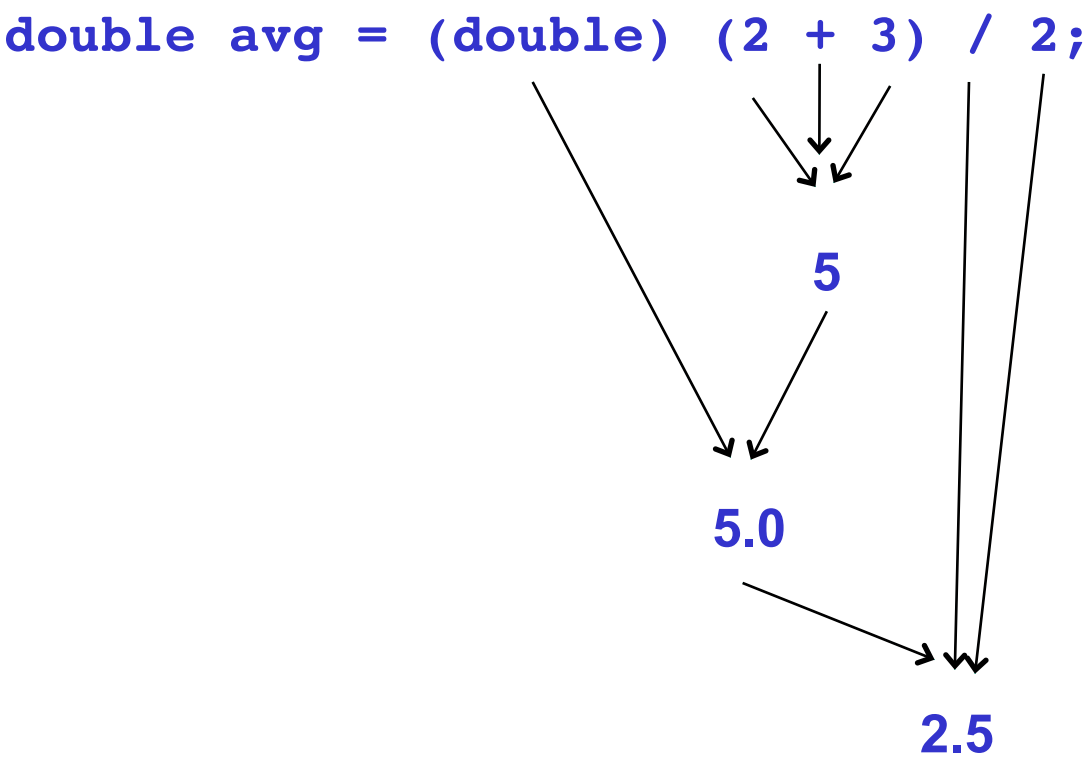

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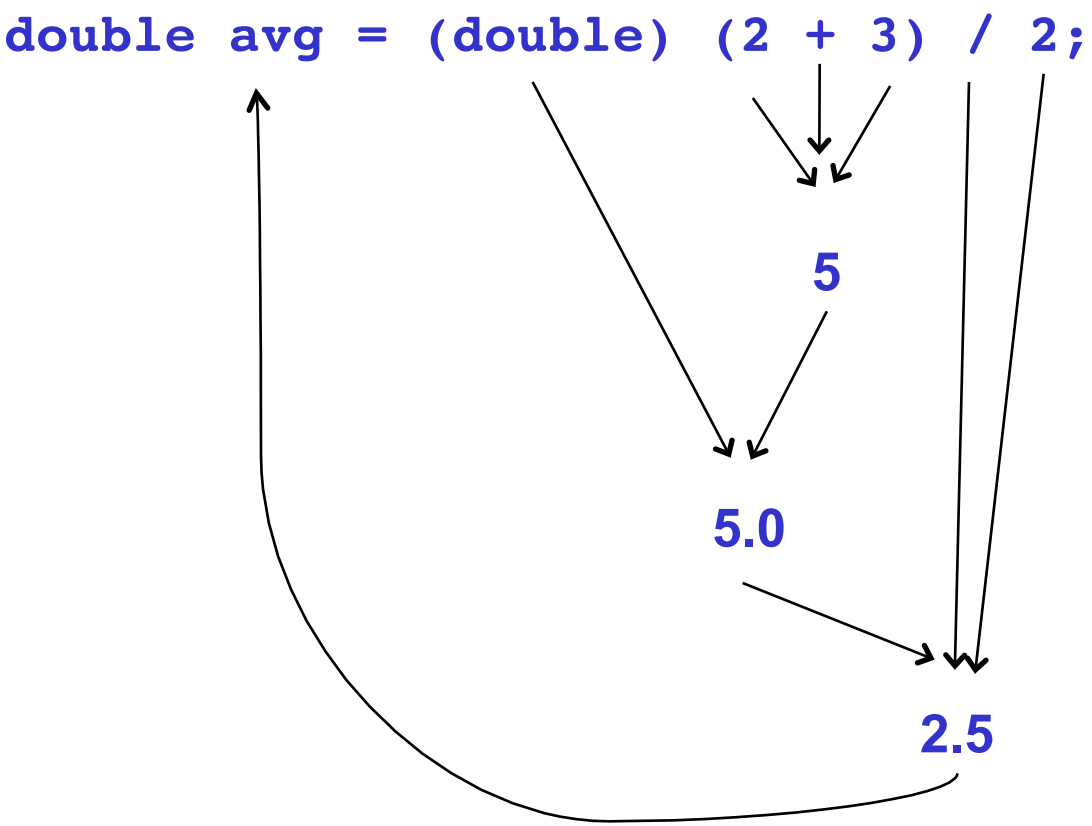

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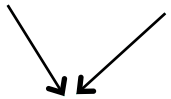

1.0

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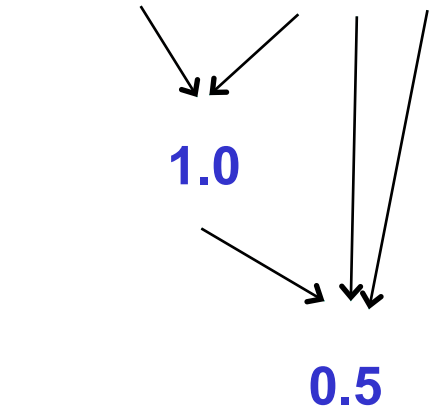

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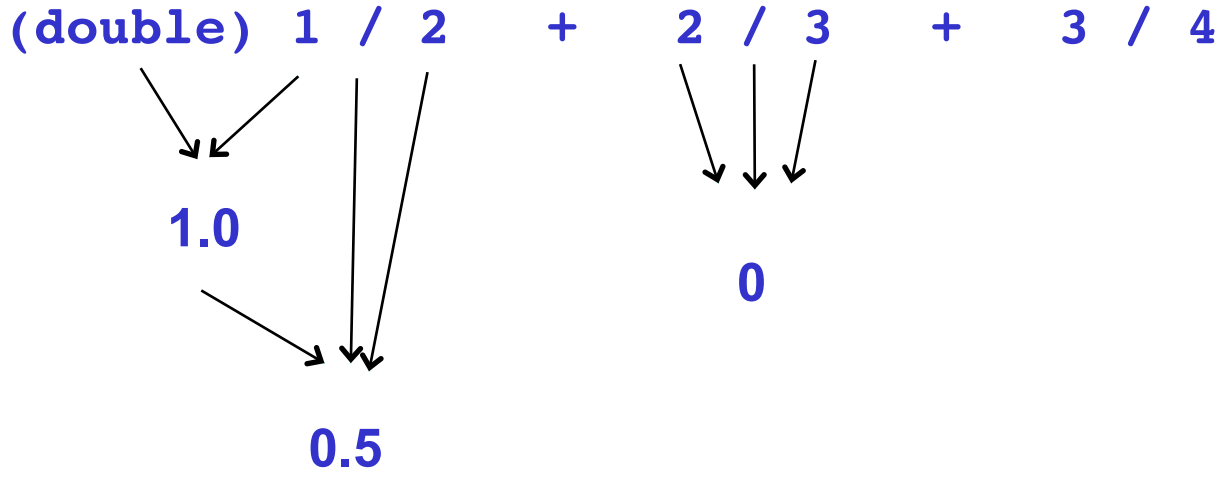

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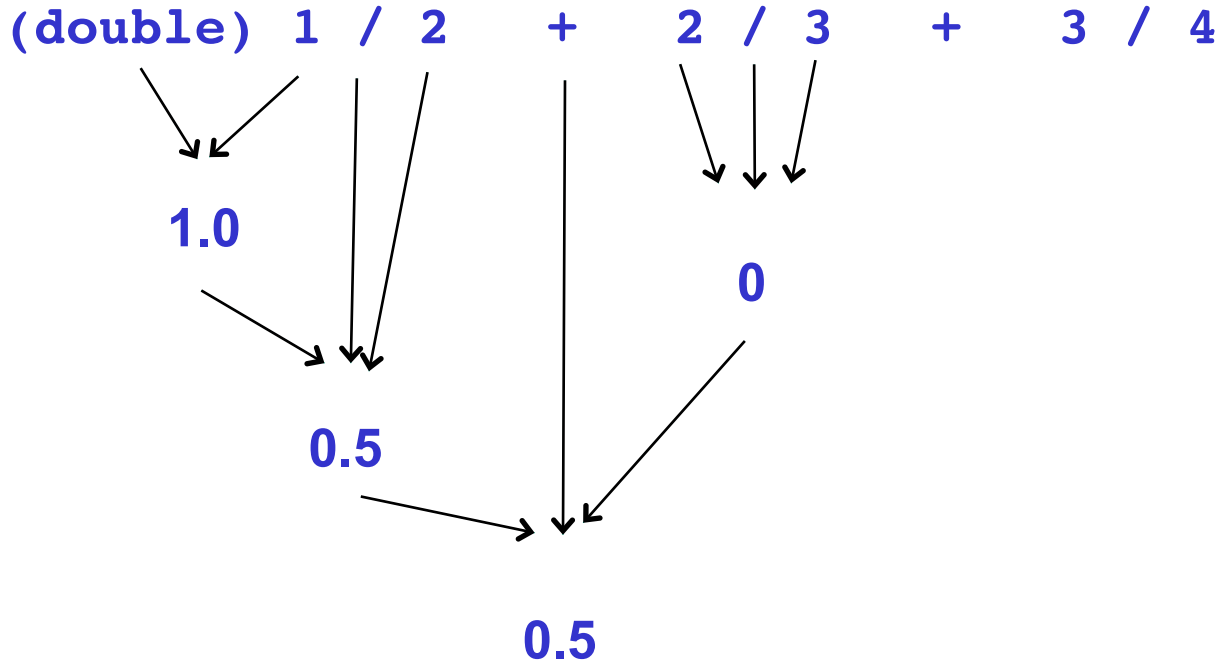

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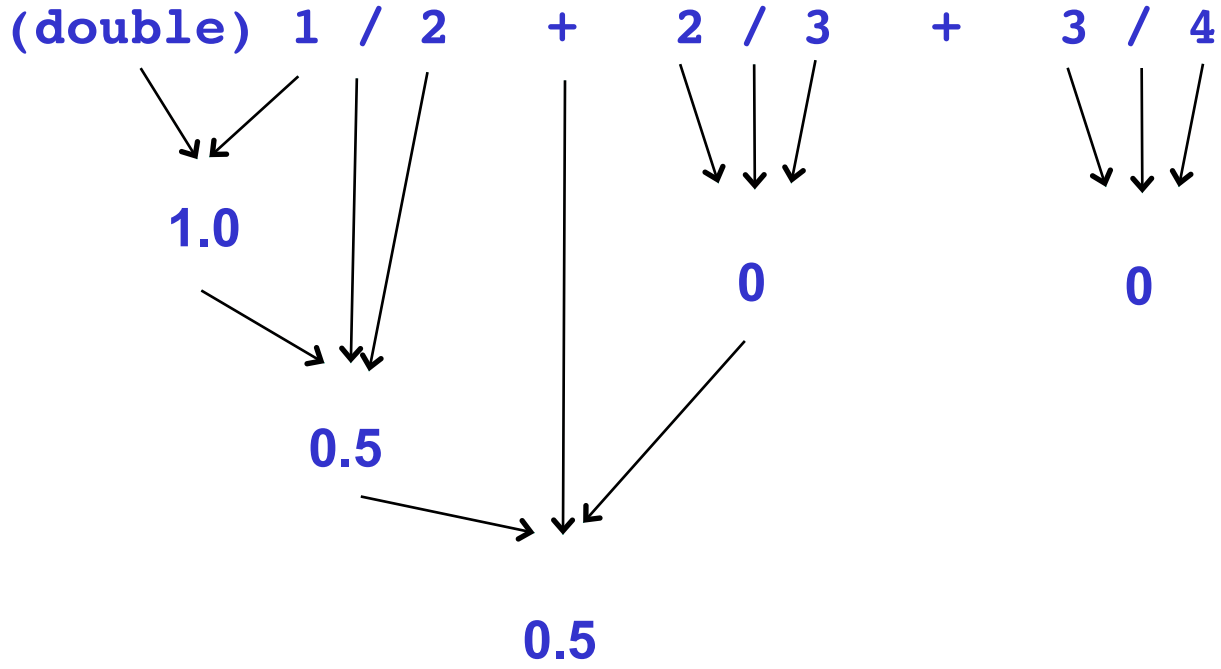

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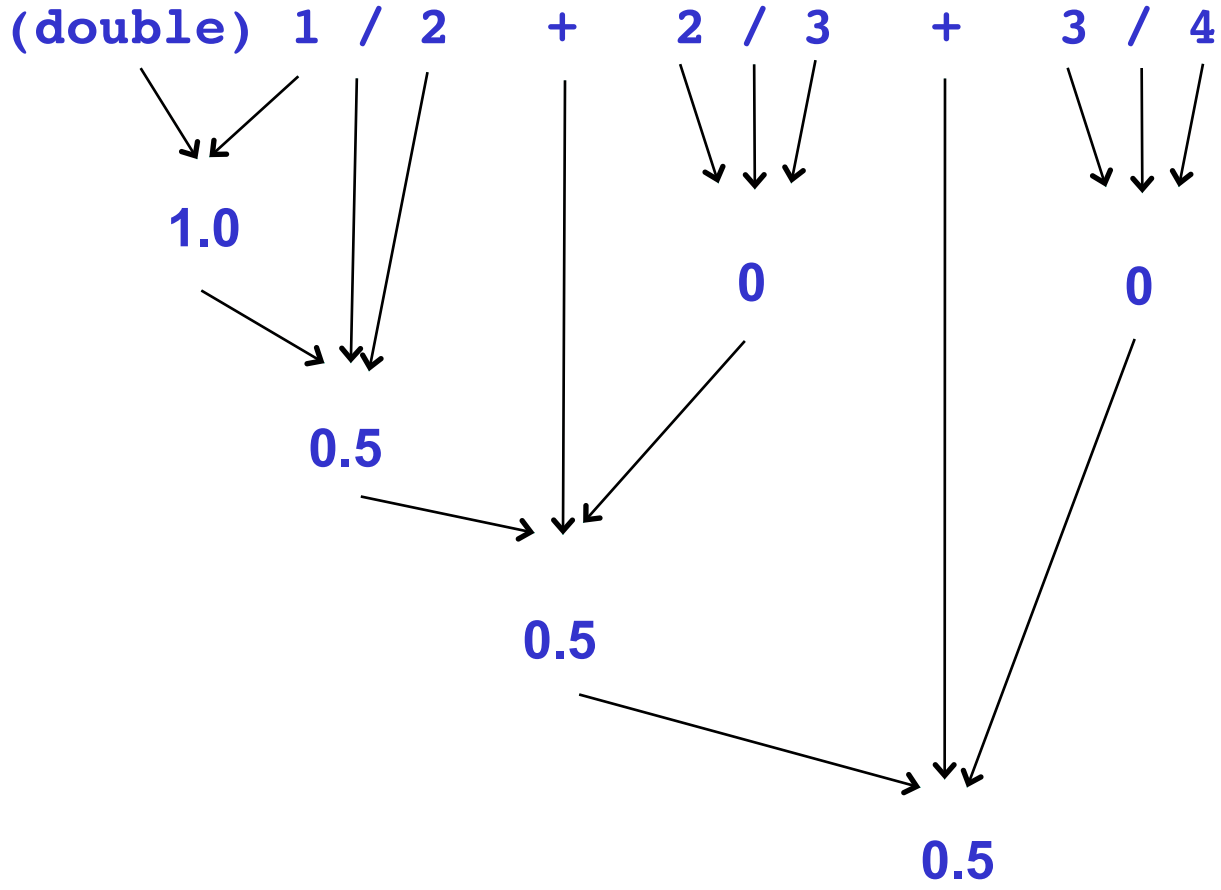

End of Oyster

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- A useful data type for representing text
- String *literals* are specified using double quotes
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Example	Result, if printed
`"Hello" + "there"`	`Hellothere`
`"Hello " + "there"`	`Hello there`
`"" + "" + ""`	

1.7 Strings

- **Declarations and assignments are the same as before.**

```
String s1 = "ei";
```

Variable Name	Value
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String s2 = s1 + s1;
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```
String s1 = "ei";

String s2 = s1 + s1;

String s3 = s2 + "o";
```

Variable Name	Value
s1	ei
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1.7 Strings

- **Conversion from other expression types to String produces the text form of their values.**
- **Given a String `s`, `s.length()` returns the length of the string in characters.**

Expression	Comments
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`int length = msg.length()`	Returns the number of characters in the string. In this case, 6 is returned.

End of Oyster

Oyster 9

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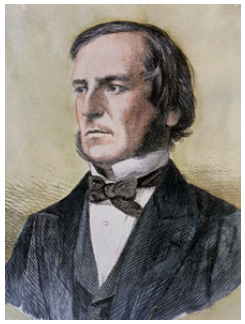
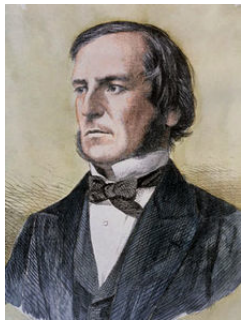
- Named after George Bool



  - 19th century logician and mathematician
  - But lower case *b* is important

1.8 The `boolean` data type

- Useful for representing two-valued concepts
  - `True vs. false`
  - `Heads vs. tails`
  - `Open vs. closed`
- Named after George Bool
  - 19th century logician and mathematician
  - But lower case *b* is important
- Only two constants (lower case is important)
  - `true`
  - `false`



1.8 The `boolean` data type

- **Mathematical operators work as expected, though some are spelled strangely**
  - **== for equality**
  - **!= for inequality**
  - **<= for ≤, etc.**

Expression	Value
`3 > 4`	`false`

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The usual rules of conversion apply here. The `int 7` is converted to the `double 7.0` and the comparison with `3.5` is then made.

1.8 The `boolean` data type

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1.8 The `boolean` data type

- **Logical operators are also available.**
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    - `!p` is `true` if `p` is `false`
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1.8 The `boolean` data type

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  - **And**
    - `p && q` is `true` if *both* `p` and `q` have the value `true`
    - Works as expected for English meaning of *and*

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1.8 The `boolean` data type

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    - `p || q` is `false` only if `p` is `false` and `q` is `false`
    - This is different from the way we use *or* in English
      - I am going to the store or I am going to a movie
      - Means one or the other, but not both

1.8 The `boolean` data type

- **Examples**

p	q	Expression	Value
`true`		`!p`	`false`
`false`		`!p`	`true`

1.8 The `boolean` data type

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1.8 The `boolean` data type

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1.8 The `boolean` data type

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1.8 The `boolean` data type

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1.8 The `boolean` data type

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1.8 The `boolean` data type

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`true`	`false`	`p && q`	`false`
		`p || !p`	`true`
		`p && !p`	`false`
`true`	`true`	`p || q`	`true`
`true`	`true`	`(p || q) && !(p && q)`	`false`

End of Oyster

Monolog 10

1.9 Conclusion

- What is a *type*?
  - A classification of items in the world based on
    - The kinds of things an item can do
    - The
  - integers, real numbers, character strings, true/false values
- Types are also defined by the operations associated with them
- Data types in computer science
  - Represent values of interest
  - Allow operations that make sense
- Built in data types (in this module)
  - For representing integers, interest rates, names, addresses, facts
- Later, we design our own types
  - Bank account, hockey player, song
- The best choice of data type is not always obvious
  - You may start with one and change your mind later
- There are rarely right or wrong choices
  - But a choice will have its advantages and disadvantages
  - Picking a suitable data type is an engineering process and is based on currently understood constraints and best planning for the future. The future can at times seem uncertain.

End of Monologue