Primitive data types, expressions, and variables

How the computer sees the world

- Internally, the computer stores everything in terms of 1's and 0's
  - Example:

    `h` → `0110100`

    `"hi"` → `0110100 0110101`

    `104` → `0110100`

- How can the computer tell the difference between an `h` and `104`?

Data types

- **data type**: A category of data values.
  - Example: integer, real number, string

- Data types are divided into two classes:
  - **primitive types**: Java's built-in *simple* data types for numbers, text characters, and logic.
  - **object types**: Coming soon!

Primitive types

- Java has eight primitive types. Here are two examples:

Name	Description	Examples
`int`	integers	`42, -3, 0, 926394`
`double`	real numbers	`3.4, -2.53, 91.4e3`

- Numbers with a decimal point are treated as real numbers.
- Question: Isn't every integer a real number? Why bother?

Integer or real number?

- Which category is more appropriate?

integer (`int`)	real number (`double`)

1. Temperature in degrees Celsius
2. The population of lemmings
3. Your grade point average
4. A person's age in years
5. A person's weight in pounds
6. A person's height in meters
7. Number of miles traveled
8. Number of dry days in the past month
9. Your locker number
10. Number of seconds left in a game
11. The sum of a group of integers
12. The average of a group of integers

- credit: Kate Deibel, http://www.cs.washington.edu/homes/deibel/CATs/

Other Primitive Data Types

Discrete Types

```
byte
short
int
long
```

Continuous Types

```
float
double
```

Non-numeric Types

```
boolean
char
```

Data Type Representations

Type	Representation	Bits	Bytes	#Values
`boolean`	`True` or `False`	1	N/A	2
`char`	‘a’ or ‘7’ or ‘\n’	16	2	2^{16} = 65,536
`byte`	…,-2,-1,0,1,2,…	8	1	2^{8} = 256
`short`	…,-2,-1,0,1,2,…	16	2	2^{16} = 65,536
`int`	…,-2,-1,0,1,2,…		4	> 4.29 million
`long`	…,-2,-1,0,1,2,…		8	> 18 quintillion
`float`	0.0, 10.5, -100.7	32		
`double`	0.0, 10.5, -100.7	64		

Manipulating data via expressions

- **expression**: A data value or a set of operations that produces a value.
  - Examples:

```
1 + 4 * 3
3
"CSE142"
(1 + 2) % 3 * 4
```

Operators

- Arithmetic operators we will use:
  - `+` addition
  - `-` subtraction or negation
  - `*` multiplication
  - `/` division
  - `%` modulus, a.k.a. remainder

Evaluating expressions

- When Java executes a program and encounters an expression, the expression is *evaluated* (i.e., computed).
  - Example: `3 * 4` *evaluates* to `12`

- `System.out.println(3 * 4)` *prints* `12` (after evaluating `3 * 4`)
  - How could we print the text `3 * 4` on the console?

Evaluating expressions: Integer division

- When dividing integers, the result is also an integer: the quotient.
  - Example: `14 / 4` evaluates to `3`, not `3.5` (truncate the number)
  - Examples:
    - `1425 / 27` is `52`
    - `35 / 5` is `7`
    - `84 / 10` is `8`
    - `156 / 100` is `1`
    - `24 / 0` is illegal (what do you think happens?)

Evaluating expressions: The modulus (%)

- The modulus computes the remainder from a division of integers.
  - Example: `14 % 4` is `2`
    `1425 % 27` is `21`

```
   3
4 ) 14
   12
    2
```

```
    52
27 ) 1425
    135
     75
     54
     21
```

- What are the results of the following expressions?

```
45 % 6
4 % 2
8 % 20
11 % 0
```

Applying the modulus

- What expression obtains…
  - the last digit (unit's place) of a number?
    - Example: From `230857`, obtain the `7`.
  - the last 4 digits of a Social Security Number?
    - Example: From `658236489`, obtain `6489`.
  - the second-to-last digit (ten's place) of a number?
    - Example: From `7342`, obtain the `4`.

Applying the modulus

- How can we use the % operator to determine whether a number is odd?
- How about if a number is divisible by, say, 27?

Precision in real numbers

- The computer internally represents real numbers in an imprecise way.

- Example:

```
System.out.println(0.1 + 0.2);
```

  - The output is `0.30000000000000004`!

Precedence

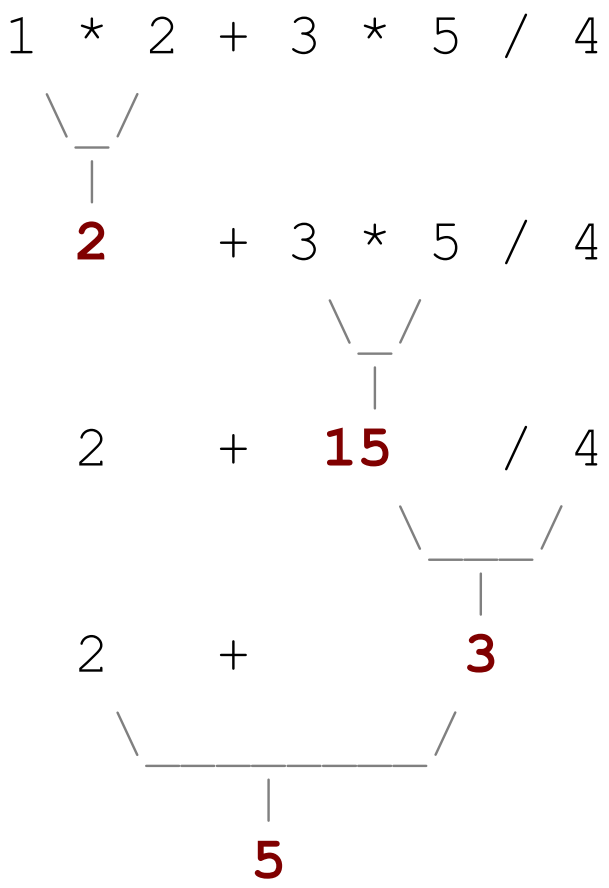
- **precedence**: Order in which operations are computed in an expression.
  - Operators on the same level are evaluated from left to right.

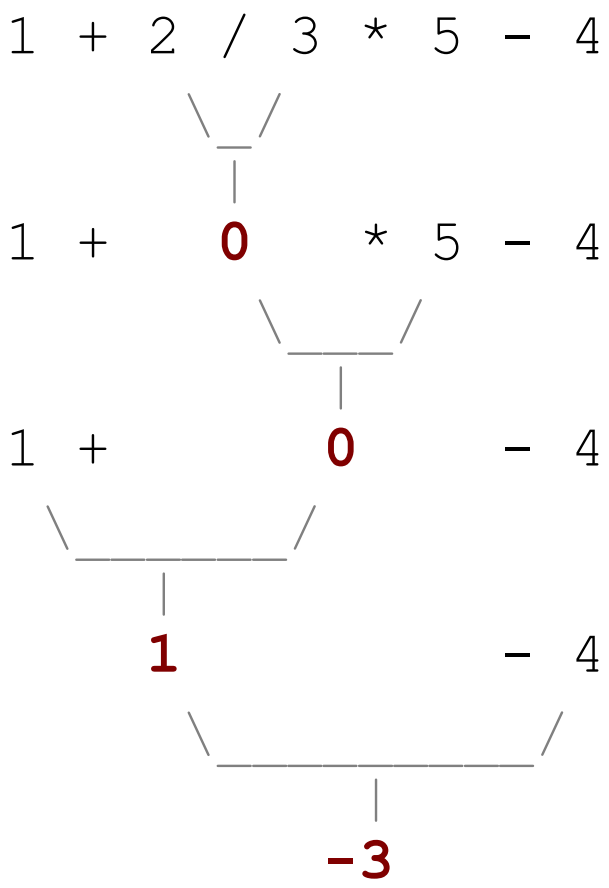
    Example: `1 - 2 + 3` is `2` (not `-4`)
  - Spacing does not affect order of evaluation.

    Example: `1+3 * 4-2` is `11`

Parentheses	`( )`
Multiplication, Division, Mod	`*  /  %`
Addition, Subtraction	`+  -`

Precedence examples



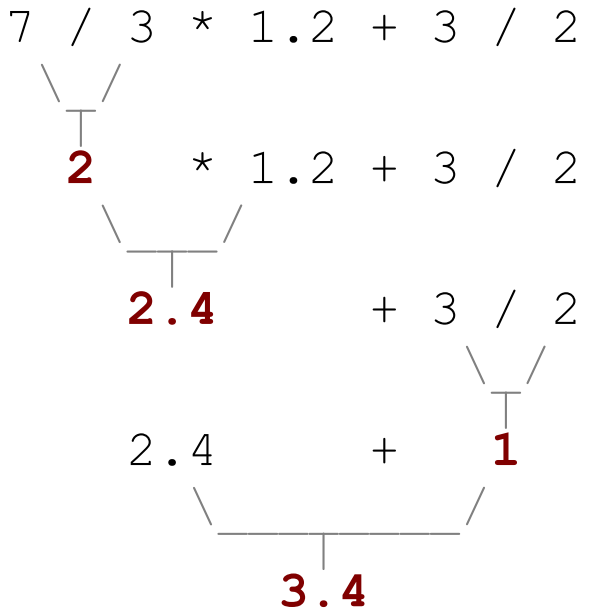


Mixing integers and real numbers

- When an operator is used on an integer and a real number, the result is a real number.
  - Examples:

    `4.2 * 3` is `12.6`
    `1 / 2.0` is `0.5`

- The conversion occurs on a *per-operator* basis. It affects only its two operands.



  - Notice how `3 / 2` is still `1` above, not `1.5`.

Concatenation: Operating on strings

- **string concatenation**: Using the + operator between a string and another value to make a longer string.

- Examples:

```
"hello" + 42    is "hello42"
1 + "abc" + 2   is "1abc2"
"abc" + 1 + 2   is "abc12"
1 + 2 + "abc"   is "3abc"
"abc" + 9 * 3   is "abc27"  (what happened here?)
"1" + 1   is "11"
4 - 1 + "abc"   is "3abc"

"abc" + 4 - 1   causes a compiler error.  Why?
```

Exercise: Combining String and Math Expressions

Write a program to print out the following output.

Use math expressions to calculate the last two numbers.

```
Your grade on test 1 was 95.1
Your grade on test 2 was 71.9
Your grade on test 3 was 82.6
Your total points:  249.6
Your average:  83.2
```

Question

- `int`s are stored in 4 bytes (32 bits)
- In 32 bits, we can store at most 2^{32} different numbers
- What happens if we take the largest of these, and add 1 to it?
  - ERROR!
  - This is known as *overflow*: trying to store something that does not fit into the bits reserved for a data type.
  - Overflow errors are **NOT** automatically detected!
    - It's the programmer's responsibility to prevent these.
  - The actual result in this case is a negative number.

Overflow example

```
int n = 2000000000;
System.out.println(n * n);
// output: -1651507200
```

- the result of n*n is 4,000,000,000,000,000,000 which needs 64-bits:

```
---------- high-order bytes -------
00110111 10000010 11011010 11001110
---------- low order bytes --------
10011101 10010000 00000000 00000000
```

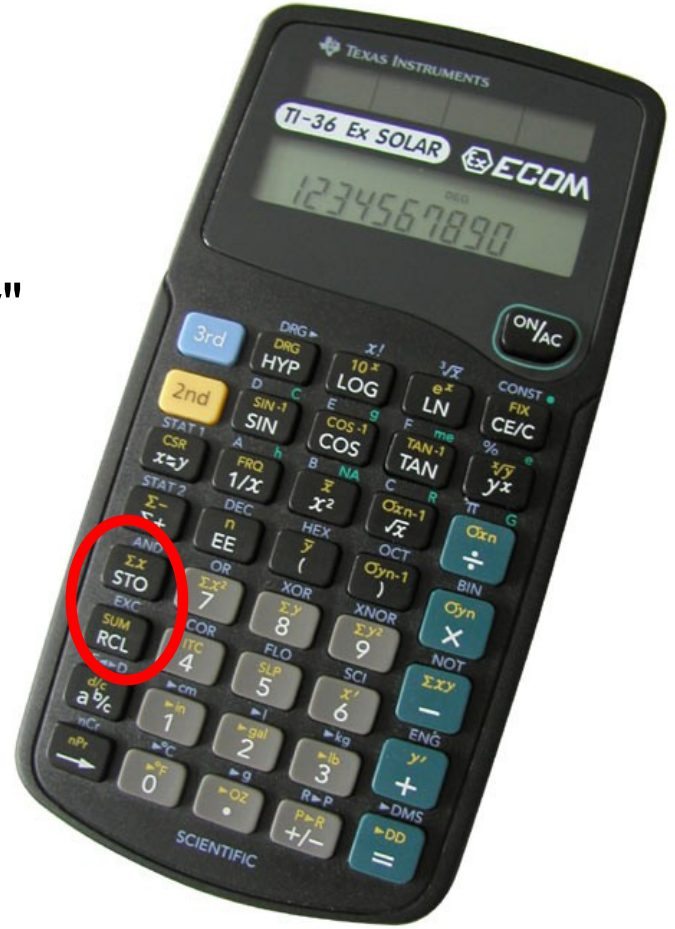
- In the case of overflow, Java discards the high-order bytes, retaining only the low-order ones
- In this case, the low order bytes represent 1651507200, and since the right most bit is a 1 the sign value is negative.

Another question:

- What happens if we create a `double` value of 1.0, and then keep dividing it by 10?
- Answer: eventually, it becomes 0.0
- This is known as *underflow*: a condition where a calculated value is smaller than what can be represented using the number of bytes assigned to its type
- Again, Java does not detect this error; it's up to the programmer to handle it.

What was the answer again?

- Evaluating expressions are somewhat like using the computer as a calculator.
  - A good calculator has "memory" keys to store and retrieve a computed value.



Variables

- **variable**: A piece of your computer's memory that is given a name and type and can store a value.
  - Usage:
    - compute an expression's result
    - store that result into a variable
    - use that variable later in the program

- Variables are a bit like preset stations on a car stereo:

Declaring variables

- To create a variable, it must be *declared*.
- Variable declaration syntax:

  <type> <name>;
- Convention: Variable identifiers follow the same rules as method names.
- Examples:

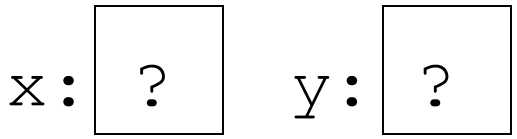
```
int x;
double myGPA;
int varName;
```

Declaring variables

- Declaring a variable sets aside a piece of memory in which you can store a value.

```
int x;
int y;
```

  - Inside the computer:



(The memory still has no value yet.)

Identifiers: Say my name!

- **identifier**: A name given to an entity in a program such as a class or method.
  - Identifiers allow us to refer to the entities.

- Examples (in **bold**):
  - `public class` **`Hello`**
  - `public static void` **`main`**
  - `double` **`salary`**

- Conventions for naming in Java (which we will follow):
  - *classes*: capitalize each word (`ClassName`)
  - *everything else*: capitalize each word after the first (`myLastName`)

Identifiers: Syntax

- First character must be a letter, `_` or `$`
- Following characters can be any of those or a number

- Examples:
  - legal:
```
susan    second_place  _myName
    TheCure ANSWER_IS_42  $variable
  method1 myMethod   name2
```
  - illegal:
```
me+u     49er     question?
     side-swipe hi thereph.d
   jim's   2%milk  suzy@yahoo.com
```

- **Remember:** Java is case-sensitive (`name` is different from `Name`)

Identifiers: Keywords

- **keyword**: An identifier that you cannot use, because it already has a reserved meaning in the Java language.
- Complete list of Java keywords:

`abstract`	`default`	`if`	`private`	`this`
`boolean`	`do`	`implements`	`protected`	`throw`
`break`	**`double`**	`import`	**`public`**	`throws`
`byte`	`else`	`instanceof`	`return`	`transient`
`case`	`extends`	**`int`**	**`short`**	`try`
`catch`	`final`	`interface`	**`static`**	**`void`**
`char`	`finally`	**`long`**	`strictfp`	`volatile`
`class`	**`float`**	`native`	`super`	`while`
`const`	`for`	`new`	`switch`	
`continue`	`goto`	`package`	`synchronized`	

- NB: Because Java is case-sensitive, you could technically use `Class` or `cLaSs` as identifiers, but this is very confusing and thus **strongly discouraged.**

Setting variables

- **assignment statement**: A Java statement that stores a value into a variable.
  - Variables must be declared before they can be assigned a value.

- Assignment statement syntax:

  <variable> = ***<expression>;***

- Examples:

```
x = 2 * 4;
myGPA = 3.25;
```

Setting variables

- A variable can be assigned a value more than once.

- Example:

```
int x;
x = 3;
System.out.println(x);    // 3

x = 4 + 7;
System.out.println(x);    // 11
```

Using variables

- Once a variable has been assigned a value, it can be used in any expression.

```
int x;
x = 2 * 4;
System.out.println(x * 5 - 1);
```

  - The above has output equivalent to:

```
System.out.println(8 * 5 - 1);
```

- What happens when a variable is used on both sides of an assignment statement?

```
int x;
x = 3;
x = x + 2;    // what happens?
```

Errors in coding

- **ERROR:** Declaring two variables with the same name
  - Example:

```
int x;
int x;       // ERROR: x already exists
```

- **ERROR:** Reading a variable's value before it has been assigned
  - Example:

```
int x;
System.out.println(x);   // ERROR: x has no value
```

Assignment vs. algebra

- The assignment statement is not an algebraic equation!
- ***<variable>*** `=` ***<expression>*** `;` means:
  - "store the value of ***<expression>*** into ***<variable>***"
- Some people read `x = 3 * 4;` as
  - "x gets the value of `3 * 4`"
- **ERROR**: `3 = 1 + 2;` is an illegal statement, because `3` is not a variable.

Assignment and types

- A variable can only store a value of its own type.
  - Example:

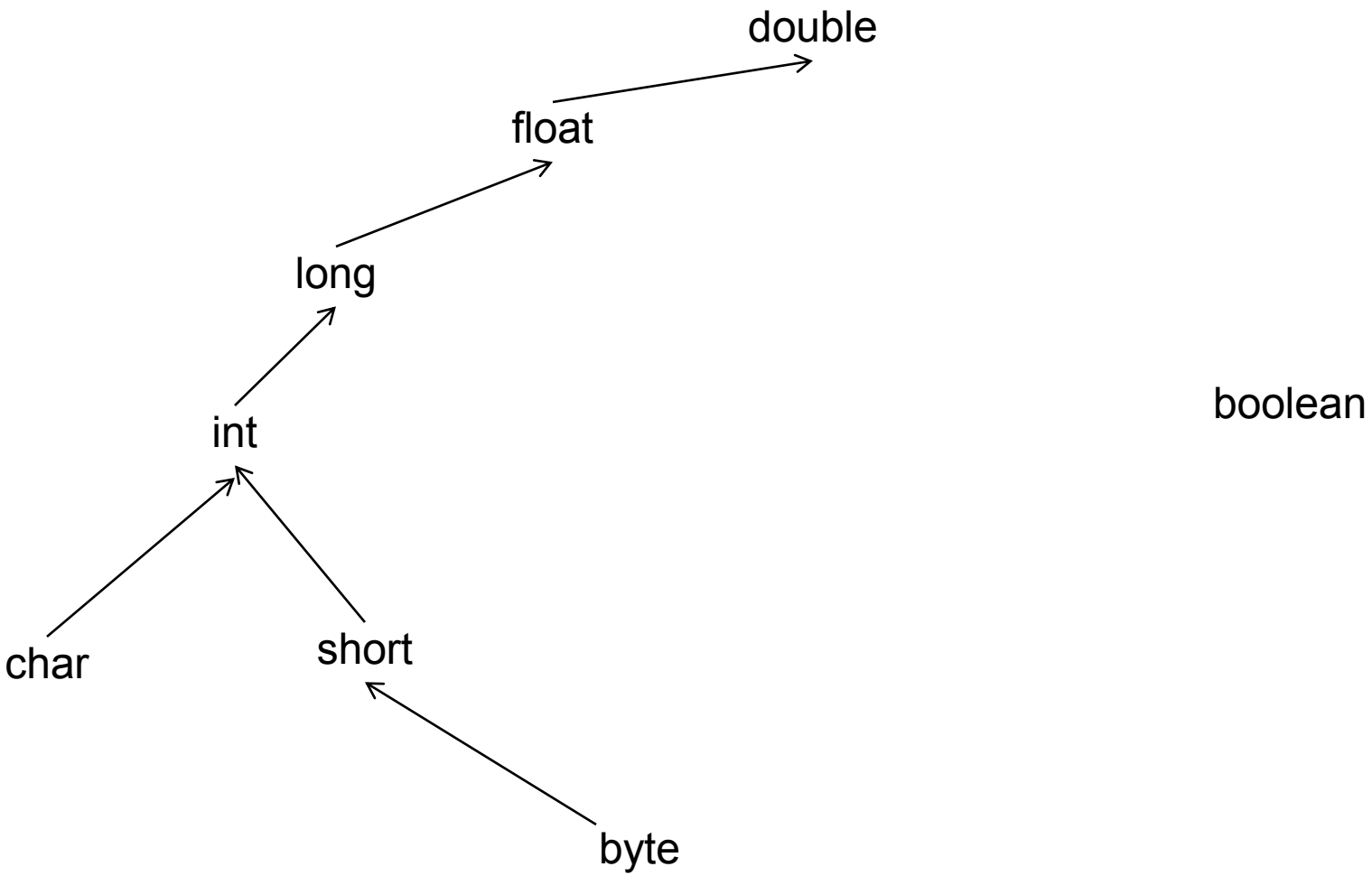
```
int x;
  x = 2.5;    // ERROR: x can only store int
```

- An `int` value can be stored in a `double` variable. Why?
  - The value is converted into the equivalent real number.
  - Example:

```
double myGPA;
myGPA = 2;
```

myGPA: 2.0

Legal Assignments



Assignment exercise

- What is the output of the following Java code?

```
int x;
x = 3;
int y;
y = x;
x = 5;
System.out.println(x);
System.out.println(y);
```

Assignment exercise

- What is the output of the following Java code?

```
int number;
number = 2 + 3 * 4;
System.out.println(number - 1);
number = 16 % 6;
System.out.println(2 * number);
```

- What is the output of the following Java code?

```
double average;
average = (11 + 8) / 2;
System.out.println(average);
average = (5 + average * 2) / 2;
System.out.println(average);
```

Shortcut: Declaring and initializing

- A variable can be declared and assigned an initial value in the same statement.

- Declaration/initialization statement syntax:

  <type> ***<name>*** = ***<expression>***;

  - Examples:

```
double myGPA = 3.95;
 int x = (11 % 3) + 12;
```

Shortcut: Declaring many variables at once

- It is legal to declare multiple variables on one line:

  <type> <name>, <name>, . . . , <name>;

  - Examples:

```
int a, b, c;
double x, y;
```

- It is also legal to declare/initialize several at once:

  <type> <name> = ***<expression>*** , . . . , ***<name>*** = ***<expression>;***

  - Examples:

```
int a = 2, b = 3, c = -4;
 double grade = 3.5, delta = 0.1;
```

- NB: The variables must be of the same type.

Shortcut: Modify and assign

- Java has several shortcut operators that allow you to quickly modify a variable's value.

Shorthand	Equivalent longer version
<variable> `+=` ***<exp>***`;`	***<variable>*** `=` ***<variable>*** `+` **(*<exp>*)**`;`
<variable> `-=` ***<exp>***`;`	***<variable>*** `=` ***<variable>*** `-` **(*<exp>*)**`;`
<variable> `*=` ***<exp>***`;`	***<variable>*** `=` ***<variable>*** `*` **(*<exp>*)**`;`
<variable> `/=` ***<exp>***`;`	***<variable>*** `=` ***<variable>*** `/` **(*<exp>*)**`;`
<variable> `%=` ***<exp>***`;`	***<variable>*** `=` ***<variable>*** `%` **(*<exp>*)**`;`

- Examples:
  - `x += 3 - 4;` `// x = x + (3 - 4);`
  - `gpa -= 0.5;` `// gpa = gpa - (0.5);`
  - `number *= 2;` `// number = number * (2);`

Shortcut: Increment and decrement

- *Incrementing* and *decrementing* `1` is used often enough that they have a special shortcut operator!

Shorthand	***Equivalent longer version***
<variable>`++;`	***<variable>*** `=` ***<variable>*** `+ 1;`
<variable>`--;`	***<variable>*** `=` ***<variable>*** `- 1;`

- Examples:

```
int x = 2;
x++;              // x = x + 1;
                  // x now stores 3

double gpa = 2.5;
gpa++;            // gpa = gpa + 1;
                  // gpa now stores 3.5
```

Putting it all together: Exercise

- Write a program that stores the following data:
  - Section 001 has 27 students.
  - Section 002 has 28 students.
  - Section 003 has 11 students.
  - Section 004 has 9 students.
  - The average number of students per section.

- Have your program print the following:

```
There are 27 students in Section 001.
...
There are <?> total students.
There are an average of <?> students per section.
```