Lesson: Language Basics

Variables

You've already learned that objects store their state in fields. However, the Java programming language also uses the term "variable" as well. This section discusses this relationship, plus variable naming rules and conventions, basic data types (primitive types, character strings, and arrays), default values, and literals.

Variables

As you learned in the previous lesson, an object stores its state in *fields*.

```
int cadence = 0;
int speed = 0;
int gear = 1;
```

The What Is an Object? discussion introduced you to fields, but you probably have still a few questions, such as: What are the rules and conventions for naming a field? Besides `int`, what other data types are there? Do fields have to be initialized when they are declared? Are fields assigned a default value if they are not explicitly initialized? We'll explore the answers to such questions in this lesson, but before we do, there are a few technical distinctions you must first become aware of. In the Java programming language, the terms "field" and "variable" are both used; this is a common source of confusion among new developers, since both often seem to refer to the same thing.

The Java programming language defines the following kinds of variables:

- **Instance Variables (Non-Static Fields)** Technically speaking, objects store their individual states in "non-static fields", that is, fields declared without the `static` keyword. Non-static fields are also known as *instance variables* because their values are unique to each *instance* of a class (to each object, in other words); the `currentSpeed` of one bicycle is independent from the `currentSpeed` of another.
- **Class Variables (Static Fields)** A *class variable* is any field declared with the `static` modifier; this tells the compiler that there is exactly one copy of this variable in existence, regardless of how many times the class has been instantiated. A field defining the number of gears for a particular kind of bicycle could be marked as `static` since conceptually the same number of gears will apply to all instances. The code `static int numGears = 6;` would create such a static field. Additionally, the keyword `final` could be added to indicate that the number of gears will never change.
- **Local Variables** Similar to how an object stores its state in fields, a method will often store its temporary state in *local variables*. The syntax for declaring a local variable is similar to declaring a field (for example, `int count = 0;`). There is no special keyword designating a variable as local; that determination comes entirely from the location in

which the variable is declared — which is between the opening and closing braces of a method. As such, local variables are only visible to the methods in which they are declared; they are not accessible from the rest of the class.

- **Parameters** You've already seen examples of parameters, both in the `Bicycle` class and in the `main` method of the "Hello World!" application. Recall that the signature for the `main` method is `public static void main(String[] args)`. Here, the `args` variable is the parameter to this method. The important thing to remember is that parameters are always classified as "variables" not "fields". This applies to other parameter-accepting constructs as well (such as constructors and exception handlers) that you'll learn about later in the tutorial.

Having said that, the remainder of this tutorial uses the following general guidelines when discussing fields and variables. If we are talking about "fields in general" (excluding local variables and parameters), we may simply say "fields". If the discussion applies to "all of the above", we may simply say "variables". If the context calls for a distinction, we will use specific terms (static field, local variables, etc.) as appropriate. You may also occasionally see the term "member" used as well. A type's fields, methods, and nested types are collectively called its *members*.

Naming

Every programming language has its own set of rules and conventions for the kinds of names that you're allowed to use, and the Java programming language is no different. The rules and conventions for naming your variables can be summarized as follows:

- Variable names are case-sensitive. A variable's name can be any legal identifier — an unlimited-length sequence of Unicode letters and digits, beginning with a letter, the dollar sign "`$`", or the underscore character "`_`". The convention, however, is to always begin your variable names with a letter, not "`$`" or "`_`". Additionally, the dollar sign character, by convention, is never used at all. You may find some situations where auto-generated names will contain the dollar sign, but your variable names should always avoid using it. A similar convention exists for the underscore character; while it's technically legal to begin your variable's name with "`_`", this practice is discouraged. White space is not permitted.
- Subsequent characters may be letters, digits, dollar signs, or underscore characters. Conventions (and common sense) apply to this rule as well. When choosing a name for your variables, use full words instead of cryptic abbreviations. Doing so will make your code easier to read and understand. In many cases it will also make your code self-documenting; fields named `cadence`, `speed`, and `gear`, for example, are much more intuitive than abbreviated versions, such as `s`, `c`, and `g`. Also keep in mind that the name you choose must not be a keyword or reserved word.
- If the name you choose consists of only one word, spell that word in all lowercase letters. If it consists of more than one word, capitalize the first letter of each subsequent word. The names `gearRatio` and `currentGear` are prime examples of this convention. If your variable stores a constant value, such as `static final int NUM_GEARS = 6`, the convention changes slightly, capitalizing every letter and separating subsequent words

with the underscore character. By convention, the underscore character is never used elsewhere.

Primitive Data Types

The Java programming language is statically-typed, which means that all variables must first be declared before they can be used. This involves stating the variable's type and name, as you've already seen:

```
int gear = 1;
```

Doing so tells your program that a field named "gear" exists, holds numerical data, and has an initial value of "1". A variable's data type determines the values it may contain, plus the operations that may be performed on it. In addition to `int`, the Java programming language supports seven other *primitive data types*. A primitive type is predefined by the language and is named by a reserved keyword. Primitive values do not share state with other primitive values. The eight primitive data types supported by the Java programming language are:

- **byte**: The `byte` data type is an 8-bit signed two's complement integer. It has a minimum value of -128 and a maximum value of 127 (inclusive). The `byte` data type can be useful for saving memory in large arrays, where the memory savings actually matters. They can also be used in place of `int` where their limits help to clarify your code; the fact that a variable's range is limited can serve as a form of documentation.
- **short**: The `short` data type is a 16-bit signed two's complement integer. It has a minimum value of -32,768 and a maximum value of 32,767 (inclusive). As with `byte`, the same guidelines apply: you can use a `short` to save memory in large arrays, in situations where the memory savings actually matters.
- **int**: The `int` data type is a 32-bit signed two's complement integer. It has a minimum value of -2,147,483,648 and a maximum value of 2,147,483,647 (inclusive). For integral values, this data type is generally the default choice unless there is a reason (like the above) to choose something else. This data type will most likely be large enough for the numbers your program will use, but if you need a wider range of values, use `long` instead.
- **long**: The `long` data type is a 64-bit signed two's complement integer. It has a minimum value of -9,223,372,036,854,775,808 and a maximum value of 9,223,372,036,854,775,807 (inclusive). Use this data type when you need a range of values wider than those provided by `int`.
- **float**: The `float` data type is a single-precision 32-bit IEEE 754 floating point. Its range of values is beyond the scope of this discussion, but is specified in section 4.2.3 of the Java Language Specification. As with the recommendations for `byte` and `short`, use a `float` (instead of `double`) if you need to save memory in large arrays of floating point numbers. This data type should never be used for precise values, such as currency. For that, you will need to use the java.math.BigDecimal class instead. Numbers and Strings covers `BigDecimal` and other useful classes provided by the Java platform.
- **double**: The `double` data type is a double-precision 64-bit IEEE 754 floating point. Its range of values is beyond the scope of this discussion, but is specified in section 4.2.3 of

the Java Language Specification. For decimal values, this data type is generally the default choice. As mentioned above, this data type should never be used for precise values, such as currency.

- **boolean**: The `boolean` data type has only two possible values: `true` and `false`. Use this data type for simple flags that track true/false conditions. This data type represents one bit of information, but its "size" isn't something that's precisely defined.
- **char**: The `char` data type is a single 16-bit Unicode character. It has a minimum value of `'\u0000'` (or 0) and a maximum value of `'\uffff'` (or 65,535 inclusive).

In addition to the eight primitive data types listed above, the Java programming language also provides special support for character strings via the java.lang.String class. Enclosing your character string within double quotes will automatically create a new `String` object; for example, `String s = "this is a string";`. `String` objects are *immutable*, which means that once created, their values cannot be changed. The `String` class is not technically a primitive data type, but considering the special support given to it by the language, you'll probably tend to think of it as such. You'll learn more about the `String` class in Simple Data Objects

Default Values

It's not always necessary to assign a value when a field is declared. Fields that are declared but not initialized will be set to a reasonable default by the compiler. Generally speaking, this default will be zero or `null`, depending on the data type. Relying on such default values, however, is generally considered bad programming style.

The following chart summarizes the default values for the above data types.

Data Type	Default Value (for fields)
byte	0
short	0
int	0
long	0L
float	0.0f
double	0.0d
char	'\u0000'
String (or any object)	null

boolean	false

Local variables are slightly different; the compiler never assigns a default value to an uninitialized local variable. If you cannot initialize your local variable where it is declared, make sure to assign it a value before you attempt to use it. Accessing an uninitialized local variable will result in a compile-time error.

Literals

You may have noticed that the `new` keyword isn't used when initializing a variable of a primitive type. Primitive types are special data types built into the language; they are not objects created from a class. A *literal* is the source code representation of a fixed value; literals are represented directly in your code without requiring computation. As shown below, it's possible to assign a literal to a variable of a primitive type:

```
boolean result = true;
char capitalC = 'C';
byte b = 100;
short s = 10000;
int i = 100000;
```

Integer Literals

An integer literal is of type `long` if it ends with the letter `L` or `l`; otherwise it is of type `int`. It is recommended that you use the upper case letter `L` because the lower case letter `l` is hard to distinguish from the digit `1`.

Values of the integral types `byte`, `short`, `int`, and `long` can be created from `int` literals. Values of type `long` that exceed the range of `int` can be created from `long` literals. Integer literals can be expressed by these number systems:

- Decimal: Base 10, whose digits consists of the numbers 0 through 9; this is the number system you use every day
- Hexadecimal: Base 16, whose digits consist of the numbers 0 through 9 and the letters A through F
- Binary: Base 2, whose digits consists of the numbers 0 and 1 (you can create binary literals in Java SE 7 and later)

For general-purpose programming, the decimal system is likely to be the only number system you'll ever use. However, if you need to use another number system, the following example shows the correct syntax. The prefix `0x` indicates hexadecimal and `0b` indicates binary:

```
// The number 26, in decimal
int decVal = 26;
//  The number 26, in hexadecimal
```

```
int hexVal = 0x1a;
// The number 26, in binary
int binVal = 0b11010;
```

Floating-Point Literals

A floating-point literal is of type `float` if it ends with the letter `F` or `f`; otherwise its type is `double` and it can optionally end with the letter `D` or `d`.

The floating point types (`float` and `double`) can also be expressed using E or e (for scientific notation), F or f (32-bit float literal) and D or d (64-bit double literal; this is the default and by convention is omitted).

```
double d1 = 123.4;
// same value as d1, but in scientific notation
double d2 = 1.234e2;
float f1  = 123.4f;
```

Character and String Literals

Literals of types `char` and `String` may contain any Unicode (UTF-16) characters. If your editor and file system allow it, you can use such characters directly in your code. If not, you can use a "Unicode escape" such as `'\u0108'` (capital C with circumflex), or `"S\u00ED Se\u00F1or"` (Sí Señor in Spanish). Always use 'single quotes' for `char` literals and "double quotes" for `String` literals. Unicode escape sequences may be used elsewhere in a program (such as in field names, for example), not just in `char` or `String` literals.

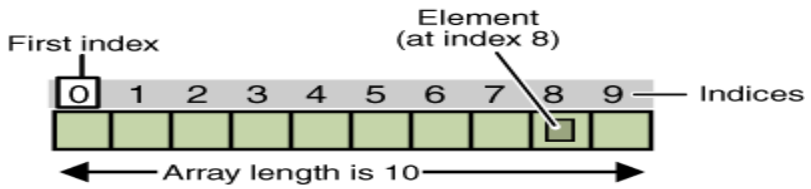
The Java programming language also supports a few special escape sequences for `char` and `String` literals: `\b` (backspace), `\t` (tab), `\n` (line feed), `\f` (form feed), `\r` (carriage return), `\"` (double quote), `\'` (single quote), and `\\` (backslash).

There's also a special `null` literal that can be used as a value for any reference type. `null` may be assigned to any variable, except variables of primitive types. There's little you can do with a `null` value beyond testing for its presence. Therefore, `null` is often used in programs as a marker to indicate that some object is unavailable.

Finally, there's also a special kind of literal called a *class literal*, formed by taking a type name and appending `".class"`; for example, `String.class`. This refers to the object (of type `Class`) that represents the type itself.

Arrays

An *array* is a container object that holds a fixed number of values of a single type. The length of an array is established when the array is created. After creation, its length is fixed. You've seen an example of arrays already, in the `main` method of the "Hello World!" application. This section discusses arrays in greater detail.



An array of ten elements

Each item in an array is called an *element*, and each element is accessed by its numerical *index*. As shown in the above illustration, numbering begins with 0. The 9th element, for example, would therefore be accessed at index 8.

The following program, `ArrayDemo`, creates an array of integers, puts some values in it, and prints each value to standard output.

```
class ArrayDemo {
    public static void main(String[] args) {
        // declares an array of integers
        int[] anArray;

        // allocates memory for 10 integers
        anArray = new int[10];

        // initialize first element
        anArray[0] = 100;
        // initialize second element
        anArray[1] = 200;
        // etc.
        anArray[2] = 300;
        anArray[3] = 400;
        anArray[4] = 500;
        anArray[5] = 600;
        anArray[6] = 700;
        anArray[7] = 800;
        anArray[8] = 900;
        anArray[9] = 1000;

        System.out.println("Element at index 0: "
                           + anArray[0]);
        System.out.println("Element at index 1: "
                           + anArray[1]);
        System.out.println("Element at index 2: "
                           + anArray[2]);
        System.out.println("Element at index 3: "
                           + anArray[3]);
        System.out.println("Element at index 4: "
                           + anArray[4]);
        System.out.println("Element at index 5: "
                           + anArray[5]);
        System.out.println("Element at index 6: "
                           + anArray[6]);
        System.out.println("Element at index 7: "
```

```
                        + anArray[7]);
        System.out.println("Element at index 8: "
                        + anArray[8]);
        System.out.println("Element at index 9: "
                        + anArray[9]);
    }
}
```

The output from this program is:

```
Element at index 0: 100
Element at index 1: 200
Element at index 2: 300
Element at index 3: 400
Element at index 4: 500
Element at index 5: 600
Element at index 6: 700
Element at index 7: 800
Element at index 8: 900
Element at index 9: 1000
```

In a real-world programming situation, you'd probably use one of the supported *looping constructs* to iterate through each element of the array, rather than write each line individually as shown above. However, this example clearly illustrates the array syntax. You'll learn about the various looping constructs (`for`, `while`, and `do-while`) in the Control Flow section.

Declaring a Variable to Refer to an Array

The above program declares `anArray` with the following line of code:

```
// declares an array of integers
int[] anArray;
```

Like declarations for variables of other types, an array declaration has two components: the array's type and the array's name. An array's type is written as *type*`[]`, where *type* is the data type of the contained elements; the square brackets are special symbols indicating that this variable holds an array. The size of the array is not part of its type (which is why the brackets are empty). An array's name can be anything you want, provided that it follows the rules and conventions as previously discussed in the naming section. As with variables of other types, the declaration does not actually create an array — it simply tells the compiler that this variable will hold an array of the specified type.

Similarly, you can declare arrays of other types:

```
byte[] anArrayOfBytes;
short[] anArrayOfShorts;
long[] anArrayOfLongs;
float[] anArrayOfFloats;
double[] anArrayOfDoubles;
boolean[] anArrayOfBooleans;
```

```
char[] anArrayOfChars;
String[] anArrayOfStrings;
```

You can also place the square brackets after the array's name:

```
// this form is discouraged
float anArrayOfFloats[];
```

However, convention discourages this form; the brackets identify the array type and should appear with the type designation.

Creating, Initializing, and Accessing an Array

One way to create an array is with the `new` operator. The next statement in the `ArrayDemo` program allocates an array with enough memory for ten integer elements and assigns the array to the `anArray` variable.

```
// create an array of integers
anArray = new int[10];
```

If this statement were missing, the compiler would print an error like the following, and compilation would fail:

```
ArrayDemo.java:4: Variable anArray may not have been initialized.
```

The next few lines assign values to each element of the array:

```
anArray[0] = 100; // initialize first element
anArray[1] = 200; // initialize second element
anArray[2] = 300; // etc.
```

Each array element is accessed by its numerical index:

```
System.out.println("Element 1 at index 0: " + anArray[0]);
System.out.println("Element 2 at index 1: " + anArray[1]);
System.out.println("Element 3 at index 2: " + anArray[2]);
```

Alternatively, you can use the shortcut syntax to create and initialize an array:

```
int[] anArray = {
    100, 200, 300,
    400, 500, 600,
    700, 800, 900, 1000
};
```

Here the length of the array is determined by the number of values provided between *{* and *}*.

You can also declare an array of arrays (also known as a *multidimensional* array) by using two or more sets of square brackets, such as `String[][] names`. Each element, therefore, must be accessed by a corresponding number of index values.

In the Java programming language, a multidimensional array is simply an array whose components are themselves arrays. This is unlike arrays in C or Fortran. A consequence of this is that the rows are allowed to vary in length, as shown in the following `MultiDimArrayDemo` program:

```
class MultiDimArrayDemo {
    public static void main(String[] args) {
        String[][] names = {
            {"Mr. ", "Mrs. ", "Ms. "},
            {"Smith", "Jones"}
        };
        // Mr. Smith
        System.out.println(names[0][0] + names[1][0]);
        // Ms. Jones
        System.out.println(names[0][2] + names[1][1]);
    }
}
```

The output from this program is:

```
Mr. Smith
Ms. Jones
```

Finally, you can use the built-in `length` property to determine the size of any array. The code

```
 System.out.println(anArray.length);
```

will print the array's size to standard output.

Copying Arrays

The `System` class has an `arraycopy` method that you can use to efficiently copy data from one array into another:

```
public static void arraycopy(Object src, int srcPos,
                             Object dest, int destPos, int length)
```

The two `Object` arguments specify the array to copy *from* and the array to copy *to*. The three `int` arguments specify the starting position in the source array, the starting position in the destination array, and the number of array elements to copy.

The following program, `ArrayCopyDemo`, declares an array of `char` elements, spelling the word "decaffeinated". It uses `arraycopy` to copy a subsequence of array components into a second array:

```
class ArrayCopyDemo {
    public static void main(String[] args) {
        char[] copyFrom = { 'd', 'e', 'c', 'a', 'f', 'f', 'e',
                            'i', 'n', 'a', 't', 'e', 'd' };
        char[] copyTo = new char[7];

        System.arraycopy(copyFrom, 2, copyTo, 0, 7);
        System.out.println(new String(copyTo));
    }
}
```

The output from this program is:

```
caffein
```

Questions and Exercises: Variables

Questions

1. The term "instance variable" is another name for ___.
2. The term "class variable" is another name for ___.
3. A local variable stores temporary state; it is declared inside a ___.
4. A variable declared within the opening and closing parenthesis of a method signature is called a ____.
5. What are the eight primitive data types supported by the Java programming language?
6. Character strings are represented by the class ___.
7. An ___ is a container object that holds a fixed number of values of a single type.

Exercises

1. Create a small program that defines some fields. Try creating some illegal field names and see what kind of error the compiler produces. Use the naming rules and conventions as a guide.
2. In the program you created in Exercise 1, try leaving the fields uninitialized and print out their values. Try the same with a local variable and see what kind of compiler errors you can produce. Becoming familiar with common compiler errors will make it easier to recognize bugs in your code.