CSC110 AB Notes

- Module 1 - Intro to Computers & Java Programming - Slides
- Additional code examples and videos
- Oracle Java Tutorials: Lesson - Language Basics
- Basic Introduction to Java at www3schools
  - The first couple chapters

Google Slides

What is a computer?

- A **computer** is machine that manipulates data and performs arithmetic and logical operations
- A computer consists of:
  - **Hardware** - the parts of a computer that you touch
  - **Software** - the programs and data used by the computer
- We tell a computer what to do using a **program** (application) - a set of instructions that the computer executes to perform a task

Programming Languages

- Programs are written using programming language
- A **programming language** is a set of words and symbols (tokens) that we use to write programs
- Each programming language has a **syntax** that describes how the tokens of the language can be put together to form valid **statements**
- The **semantics** of a program defines what the statements mean
- A syntactically correct program may not be semantically correct!
- A program will always do *exactly what you tell it to do*, not what we *meant* to tell it to do

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- There are many programming languages in use today such as:
  - Python
  - C++
  - JavaScript
  - C#
  - and hundreds of others…
- In this course, we will be using **Java** as our programming language of choice
- Many concepts you will learn will carry over to other languages
  - For example, most languages have for-loops, and the Java syntax is identical to C & C++

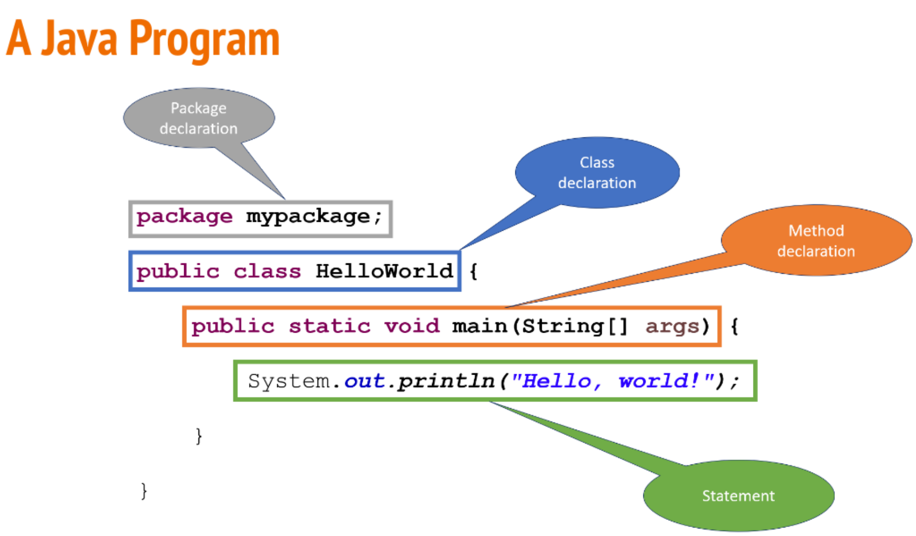
Programming languages are constantly evolving

- **Machine language** is the language of the CPU (binary code)
  - But, they are CPU-specific!
- **Assembly language** is a mnemonic device that maps human-readable identifiers to machine language
- **High level languages** are more human-readable and get converted to machine language by a compiler
- **Fourth-generation languages** are more natural-language like

The Java Programming Language

- Java was introduced in 1995
- It was created by a team at Sun Microsystems let by James Gosling
- Java is an **object-oriented programming** language (more on that later!)
- A Java program is made up of one or more **classes** that contain **methods** that contain **statements**
- Every Java application must contain a method called main which is where the program starts
- The main method often uses other classes and calls other methods

A Java Program



Comments

Comments are code that the compiler ignores - they allow the programmer to document their code.

Java has 3 comment formats:

- C style: `/* this is a comment */`
  - can extend multiple lines
- C++ style: `// this is a one line comment`
- **Javadoc:** `/** this is a javadoc comment **/`

Comments do not affect how the program runs - the serve to give hints to other programmers about what the program is doing

Use comments to clarify the *thought* behind your code, not what it does. For example, here are 3 lines of code that do the same thing:

- Bad: `a = t / c; // A is equal to t divided by c`
- Better: `a = t / c; // Compute the average`
- Best: `averageStudents = totalStudents / numberOfClasses;`
- Notice that the best use of comments is using descriptive names instead of comments!

Identifiers

- **Identifiers** are names chosen for things in their program
- **Reserved words** have a predefined meaning to the language, so you cannot use them as identifiers
  - See https://docs.oracle.com/javase/tutorial/java/nutsandbolts/_keywords.html for a list
- Java identifiers are made up of letters (A-Z), digits (0-9), and the underscore (_) and dollar sign ($) characters
- Java identifiers cannot begin with a digit
- Java identifiers are **case-sensitive**
  - So value, Value, VALUE, VaLuE, and vAlUe are 5 distinct identifiers
  - Value, _Value, Value$, and Value1 are also 4 distinct identifiers
  - Note that it is best to use descriptive *names*, not different case to differentiate identifiers

Conventions

- **Capitalize** class names
  - `Circle`
  - `GameBoard`
- Use **ALLCAPS** for constants
  - `PI`
  - `DEFAULT_LENGTH`
- **lowercase** names for packages
  - `project01`
  - `mystuff`
- **camelCase** for method & variable names
  - `avgGrade`

  - `myValue`
  - `bestCaseScenario`
  - `thisOneIsALittleBitLong`

White Space

- The spaces, blank lines, and tabs in your program are called **white space**
- White space is used to separate the tokens (symbols & words) in your program
- Extra white space in your program is ignored by the compiler
- Use white space to make your code more clear (readable)
  - But, as with comments, you can have too much of a good thing

Example

These programs are identical in what they do, but one is a bit clearer

```java
package videoexamples.chapter01;

public class HelloWorld {

    public static void main(String[] args) {

        System.out.println("Hello, world!");

    }

}
```

Use whitespace for clarity!

```java
package
videoexamples.chapter01;

public          class
HelloWorld              { public static
    void            main(String
            []


            args) {
        System.out.println

("Hello, world!"
        ) ; }

}
```

Documenting Your Code

- Strive to write code that does not need to be documented
  - Descriptive variable/method names
  - Classes/methods should encapsulate/do one thing
- Comments should be used to provide the big picture
- Use white space to make your code more readable
- Provide tests to demonstrate how your code works
- Bad programmers write complex code, good programmers write simple code

> Always code as if the guy who ends up maintaining your code will be a violent psychopath who knows where you live. Code for readability.
>
> – John F. Woods, comp.lang.c++

What Is The Purpose of Programming?

- The purpose of writing any program is to *solve a problem*

- Actually writing the code is not particularly valuable
- Companies do not pay software engineers to write code - they pay them to solve problems
    - Code is just the tool they use to solve the problems
- Your value as a programmer is in your problem-solving ability
- The reason you should learn to code is so that you can implement your solutions!

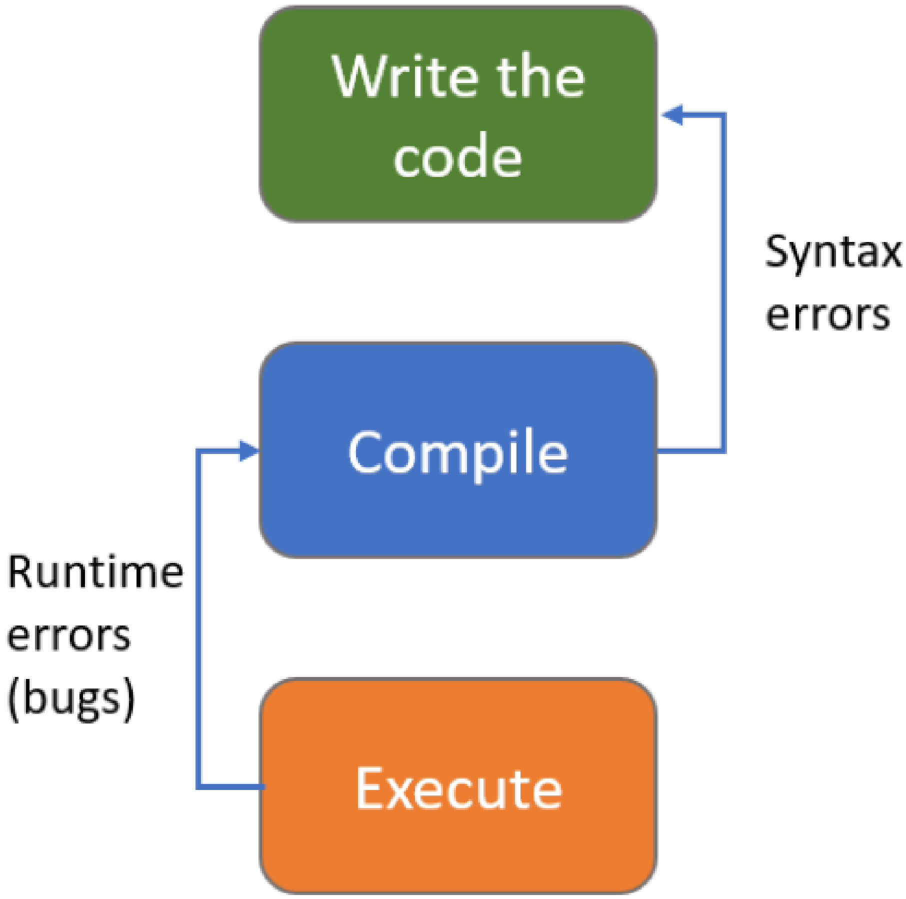
Problem-Solving With Programming

1. Understand the problem
2. Establish requirements
3. Design a solution - break the problem into manageable pieces
4. Implement your solution
5. Refine the solution & consider alternatives
6. Test your solution

The Program Development Process

1. **Requirements** – an informal description of the program's needed functionality from the user's point of view
2. **Specification** – a formal description of the programs requirements from the programmer's point of view.
3. **Preconditions & Postconditions** (what the inputs & outputs are)
4. **Design** – translating the specification into procedure
5. **Implementation** – instantiating the design (programming)
6. **Testing** – verifying that the implementation works correctly
7. **Verification & Validation -** verifying that the implementation meets the requirements & specification

How Code Runs

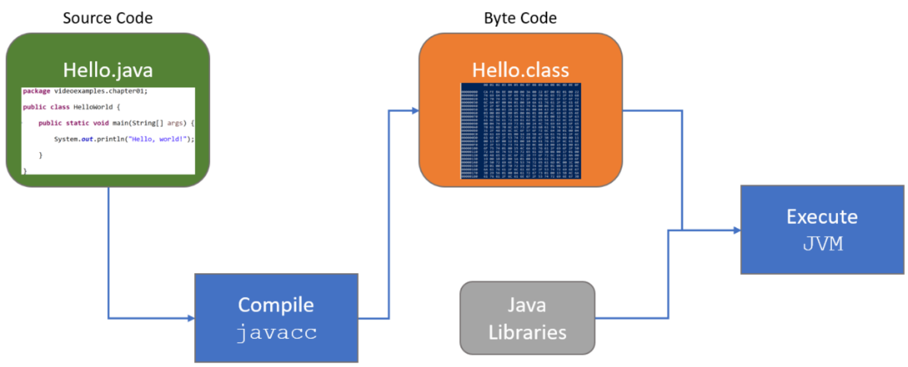


- Write your code using an editor
  - Save your code as ASCII text
- Converts (**compiles**) your **source code** to a form that the computer understands (machine language)
  - The compiler my find places where you wrote the code incorrectly (syntax errors)
  - If there are syntax errors, you will need to fix them before you move on
- Run (**execute**) your code
  - Errors at this point are called runtime errors and usually indicate a problem with the logic of your solution

How Java Code Runs

Java has a 2-step compilation process - your code is first converted into Java **Bytecode** and then the **Java Virtual Machine** executes the Java Bytecode

- Note that this means Java is more CPU-independent than other languages as it can run on any CPU that has a JVM!



Program Errors

- **Compile-time Errors** are syntax errors and other problems with your *code* that the compiler will find
- **Run-time Errors** occur during program execution and cause the program to terminate abnormally (crash)
  - Example: divide by 0, using a null reference
- **Logic Errors** occur when the program terminates successfully, but produces incorrect results
  - Example: use of an incorrect formula, incorrectly updating a variable

Development Environment

- To write and execute your own programs, you will need a development environment
- that consists of the tools you need (**toolchain**):
  - **Editor:** create & modify your source
  - **Compiler:** convert your code to executable format
  - **Test environment (Unit testing)**
  - **Debugger:** help you find errors in your program
- You can use individual programs for each step of the software development process

- There are also programs called **integrated development environments (IDEs)** that combine all the tools into one software application

Java IDEs

- There are several popular Java IDEs
    - **Eclipse**
    - IntelliJ
    - NetBeans
    - Repl.it
- They all work a little differently, but the edit/compilation/execution process is essentially the same for all of them
- You can also go hardcore and use the command line tools such as javacc to compile your source code and java (to run the JVM)

Object-Oriented Programming

- Java is an **Object-Oriented Programming Language**
- The **object** is the fundamental entity in a Java program
    - A Java program is made up of objects
- An object has some information & some operations
- Represents some real-world entity
- A particular employee in a company
- A window in a GUI
- A character in a game
- Each object handles its own processing and data management

Each object has state and behaviors

- **State - data members / fields / instance variables**
    - What an object knows about itself
- **Behaviors - members / methods / functions**
    - What an object does

The behavior of an object may change its state

- There are often multiple ways to represent a problem
- Usually there is no “one right answer”
- In fact, OOP itself is not always the answer - other paradigms such as functional programming are better at solving some problems

Methods

- Methods define the possible behaviors of the object
- Think of calling a method as “sending a message” that asks the object to do something
    - We say the sender of the method is the **client**
- The message contains the operations name and arguments

- The client doesn't care *how* the message is handled, only that it produces an expected result

Objects vs Classes

A *class* represents a abstract concept An *object* is the realization of a class

- We **instantiate** one or more objects of a specific class
- The Java new operator creates a new object

There can be multiple objects of a given class (called **instances**), but each object is an instantiation of a single class

Examples

Class	Example Objects
Room	Kitchen, Bedroom, Study, Bathroom
Movie	Star Wars, Clueless, Knives Out, Casablanca
Team	Diamondbacks, Sun Devils, Cardinals, JoesGarage
CSClass	CSC110AA, CSC205, CSC230, CSC240
States	Arizona, Louisiana, New York, Alaska

Programming Basics

Below are the two beginning chapters for learning Java, but the overall tree for all the chapters can be viewed here: https://docs.oracle.com/javase/tutorial/java/TOC.html

- Object-Oriented Programming Concepts
- Java Tutorials: Language Basics

```java
// -------------------Hello World------------------
package
mypackage;

public class helloWorld {
    public static void main(String[] args) {
      System.out.println("Hello World!");
    }
}

// -------------------Commenting Styles------------------

// Comment style 1
/* Comment style 2 */
/** Javadoc **/
```

```java
// -------------------Data Types------------------

String
Text = "This is a string";
int
myNum = 15;
char
alphabet = 'b';
float
fractionalNumber = 15.44f;  // End floats with f
float scientificNumber = 34e3f;  // Scientific numbers can be used as well
double d1 = 12E4d;  // End doubles with d
double veryLongNumber = 15.22222323232;
boolean thisIsTrue = true;
boolean thisIsAlsoTrue = 1;
long myLong = 1_500_000_000_000_000_000L;  // Remember to end longs with an L

// -------------------Constants------------------

final int myNum = 15;  // Makes variable read-only.
constant float myFloat = 15.12f;

// -------------------Declaring & Initializing------------------

int
x, y, z;
x = y = z = 50;

int
x = 5, y = 5, z = 5;

// -------------------Printing------------------

System.out.println("Hello World!");       // Prints newline, doesn't require args
System.out.print("Hello World!\n");       // Does not print a newline, requires args
System.out.println("" + 2 + 4 + 56 + 2);  // Passing a string as first arg concats
```

Data Types

Data Type	Size	Description
byte	1 byte	Stores whole numbers from **-128** to **127**

Data Type	Size	Description
short	2 bytes	Stores whole numbers from **-32,768** to **32,767**
int	4 bytes	Stores whole numbers from **-2,147,483,648** to **2,147,483,647**
long	8 bytes	Stores whole numbers from **-9,223,372,036,854,775,808** to **9,223,372,036,854,775,807**
float	4 bytes	Stores fractional numbers. Sufficient for storing **6** to **7** decimal digits
double	8 bytes	Stores fractional numbers. Sufficient for storing **15** decimal digits
boolean	1 bit	Stores true or false values
char	2 bytes	Stores a single character/letter or ASCII values

Objects

- An object is a software bundle of related state and behavior.
  - *fields* and *methods*
- In Java, the information about a class are stored in **fields** *(Attributes in python)*.
- **Methods** are the actions that an object can perform
- **Data Encapsulation:** Hiding internal state and requiring all interaction to be performed through an object's methods.

Benefits of bundling code into individual software objects:

1. **Modularity:** The source code for an object can be written and maintained independently of the source code for other objects. Once created, an object can be easily passed around inside the system.
2. **Information-hiding:** By interacting only with an object's methods, the details of its internal implementation remain hidden from the outside world.
3. **Code re-use:** If an object already exists (perhaps written by another software developer), you can use that object in your program. This allows specialists to implement/test/debug complex, task-specific objects, which you can then trust to run in your own code.
4. **Pluggability and debugging ease:** If a particular object turns out to be problematic, you can simply remove it from your application and plug in a different object as its replacement. This is analogous to fixing mechanical problems in the real world. If a bolt breaks, you replace it, not the entire machine.

Example

Create the class

```
class Bicycle {

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

    void changeCadence(int newValue) {
         cadence = newValue;
    }

    void changeGear(int newValue) {
         gear = newValue;
    }

    void speedUp(int increment) {
         speed = speed + increment;
    }

    void applyBrakes(int decrement) {
         speed = speed - decrement;
    }

    void printStates() {
         System.out.println("cadence:" +
             cadence + " speed:" +
             speed + " gear:" + gear);
    }
}
```

Instantiate The Class & Invoke Methods

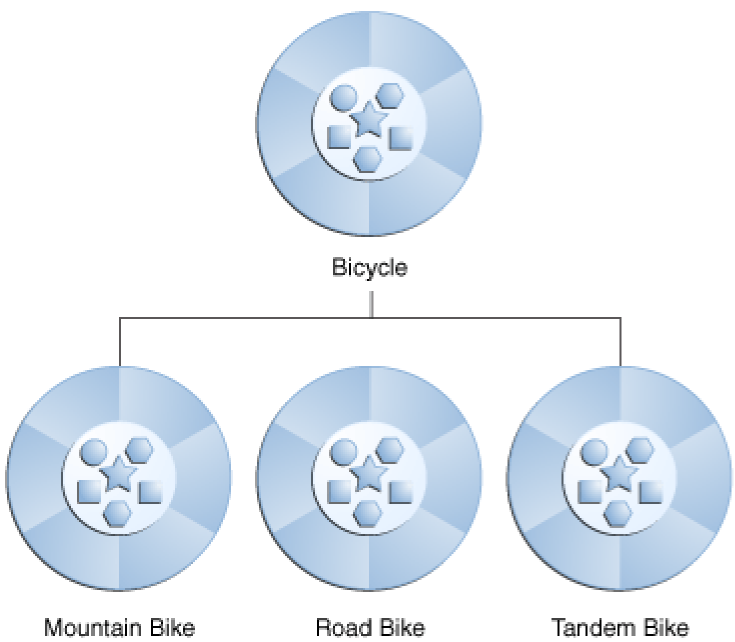
```
class BicycleDemo {
    public static void main(String[] args) {

        // Create two different
        // Bicycle objects
        Bicycle bike1 = new Bicycle();
        Bicycle bike2 = new Bicycle();

        // Invoke methods on
        // those objects
        bike1.changeCadence(50);
        bike1.speedUp(10);
        bike1.changeGear(2);
        bike1.printStates();
```

```
        bike2.changeCadence(50);
        bike2.speedUp(10);
        bike2.changeGear(2);
        bike2.changeCadence(40);
        bike2.speedUp(10);
        bike2.changeGear(3);
        bike2.printStates();
    }
}
```

Output

```
cadence:50
speed:10
gear:2
cadence:40
speed:20
gear:3
```

Inheritance



A hierarchy of bicycle classes.

- Inheritance allows a class to *inherit* commonly used state and behavior from other classes.

- In this example, `Bicycle` is now the **superclass** of the other three classes.
  - Each class can only have one superclass, but can have unlimited subclasses.

Inheritance Syntax

```
class MountainBike extends Bicycle {

    // new fields and methods defining
    // a mountain bike would go here

}
```

- `MountainBike` now has all the same fields and methods as `Bicycle`, yet it allows its code to focus exclusively on the features that make it unique.
- Remember to properly document the state and behavior that each superclass defines, since that code will not appear in the source file of each subclass.

Interface

Methods form an object's *interface* with the outside world.

- Similar to the buttons on the front of a tv set. The buttons are the interface between you and the inner workings on the other side.

In its most common form, an interface is a group of related methods with empty bodies. A bicycle's behavior, if specified as an interface, might appear as follows:

```
interface
Bicycle
{

    //  wheel revolutions per minute
    void changeCadence(int
    newValue
)
    ;

    void changeGear(int
    newValue
)
    ;

    void speedUp(int
    increment
)
    ;
```

```
    void applyBrakes(int
    decrement
)
    ;
}
```

To implement this interface, the name of your class would change (to a particular brand of bicycle, for example, such as ACMEBicycle), and you'd use the implements keyword in the class declaration:

```
class ACMEBicycle implements Bicycle {

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

    // The compiler will now require that methods
    // changeCadence, changeGear, speedUp, and applyBrakes
    // all be implemented. Compilation will fail if those
    // methods are missing from this class.

    void

    changeCadence(int

    newValue
) {
    cadence = newValue;
}

void changeGear(int
newValue
)
{
    gear = newValue;
}

void speedUp(int
increment
)
{
    speed = speed + increment;
}
```

```
void applyBrakes(int
decrement
)
{
    speed = speed - decrement;
}

void printStates()
{
    System.out.println("cadence:" +
        cadence + " speed:" +
        speed + " gear:" + gear);
}
}
```

- This forms a contract between a class and the outside world that is enforced by the compiler at build time.
- All methods in the interface must appear in its source code before the class will successfully compile.
- The `public` keyword needs to be added at the beginning of the implemented interface methods to actually compile the `ACMEBicycle` class.

What Is a Package?

A package is a namespace that organizes a set of related classes and interfaces.

- Similar to different folders on a PC. Keeps things organized, like having HTML in one folder, images in another, and scripts or applications in yet another.
- The Java platform provides a vast class library (a set of packages) for personal use.
  - The library is called the **Application Programming Interface (API)**.
  - Examples are:
    * `String` object
    * `File` object
    * `Socket` object

Variables

Java 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 of 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** There are 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.

Operators

Expressions, Statements, and Blocks

Control Flow Statements

ZyBooks

Computer Program Basics

A computer **program** consists of instructions executing one at a time. Basic instruction types are:

- **Input:** A program gets data, perhaps from a file, keyboard, touchscreen, network, etc.
- **Process:** A program performs computations on that data, such as adding two values like x + y.
- **Output:** A program puts that data somewhere, such as to a file, screen, network, etc.

Programs use **variables** to refer to data, like `x`, `y`, and `z`. The name is due to a variable's value varying as a program assigns a variable like`x` with new values.

Computational Thinking

Mathematical thinking became increasingly important throughout the industrial age to enable people to successfully live and work. In the information age, many people believe **computational thinking**, or creating a sequence of instructions to solve a problem, will become increasingly important for work and everyday life. A sequence of instructions that solves a problem is called an **algorithm**.

Basic Input

A **Scanner** is a text parser that can get numbers, words, or phrases from an input source such as the keyboard. Getting input is achieved by first creating a Scanner object via the statement: `Scanner scnr = new Scanner(System.in);`. System.in corresponds to keyboard input. Then, given `Scanner` object `scnr`, the following statement gets an input value and assigns x with that value: `x = scnr.nextInt() ;`.

```
// Step 1 - Import the scanner
import java


.
util.Scanner

// Step 2 - Instantiate a scanner object
Scanner
scn = new Scanner(System.in);  // Gets input

// Step 3 - Run the desired object method
age = scn.nextInt();  // Gets the int from the input
```

Example 1

```
import java.util.Scanner;

public class Main {
    public static void main(String[] args) {
        System.out.print("Please enter a number: ");
        Scanner scnr = new Scanner(System.in);

        int age = scnr.nextInt();
        int ageMultiplier = 3;

        System.out.print(age);
        System.out.print(" is what you think your cat's age is. It's actuallY: ");
```

```
        System.out.println(age * ageMultiplier);
    }
}
```

Basic output: Text

- Text in double quotes is a **string literal**.
- `System.out.println` prints a **newline** and `System.out.print` does not.

Whitespace

Whitespace refers to blank spaces (space and tab characters) between items within a statement and blank lines between statements (called newlines). A compiler ignores most whitespace.

- Use blank lines to separate conceptually distinct statements.
- Indent lines the same amount.
- Align items to reduce visual clutter.
- Use a single space before and after any operators like `=`, `+`, `*`, or `/` to make statements more readable.

Good Example of Whitespace

```
import java.util.Scanner;

public class WhitespaceEx {
   public static void main(String[] args) {
      Scanner scnr = new Scanner(System.in);
      int myFirstVar;    // Aligned comments yield less
      int yetAnotherVar; // visual clutter
      int thirdVar;

      // Above blank line separates variable declarations from the rest
      System.out.print("Enter a number: ");
      myFirstVar = scnr.nextInt();

      // Above blank line separates user input statements from the rest
      yetAnotherVar = myFirstVar;         // Aligned = operators
      thirdVar      = yetAnotherVar + 1;
      // Also notice the single-space on left and right of + and =
      // (except when aligning the second = with the first =)

      System.out.println("Final value is " + thirdVar); // Single-space on each side of +
   }
}
```

Bad Example of Whitespace

```
import java.util.Scanner;
public class PastaCalculator {
public static void main (String [] args) {
Scanner scnr = new Scanner(System.in);int numPeople;int totalOuncesPasta;
System.out.println("Enter number of people:");
numPeople = scnr.nextInt(); totalOuncesPasta = numPeople * 3;
System.out.println("Cook "+totalOuncesPasta+" ounces of pasta.");}}
```

Errors and Warnings

Syntax Errors

When a programming language's rules on how symbols can be combined to create a program are violated.

- Such as forgetting to end a statement with a semicolon.
- An error message is generated by the compiler.

Because a syntax error is detected by the compiler, a syntax error is known as a type of **compile-time error**.

Unclear error messages

Sometimes the compiler error message refers to a line that is actually many lines past where the error actually occurred. Not finding an error at the specified line, the programmer should look to *previous* lines.

- It's good practice to fix the first error reported by the compiler and then recompile.
  - The remaining error messages may be real but are more commonly due to the compiler's confusion caused by the first error, and are irrelevant.

Logic Errors

A **logic error**, also called a **bug**, is an error that occurs while a program runs.

The term bug to describe a runtime error was popularized when in 1947 engineers discovered their program on a Harvard University Mark II computer was not working because a moth was stuck in one of the relays (a type of mechanical switch). They taped the bug into their engineering log book, still preserved today (The Moth.

Compiling Frequently

It's good practice to compile frequently after a few lines of code to make sure that everything works, instead of writing large amounts of code only to not be able to figure out which part is not working.

Compiler Warnings

A compiler will sometimes report a **warning**, which doesn't stop the compiler from creating an executable program but indicates a possible logic error.

- I.e. Some compilers will report a warning like "Warning, dividing by 0 is not defined."
- By default, Java compilers don't print every possible warning if it thinks the code may still run fine, so it's recommended to configure compilers to be more picky with warnings than the default.
  - `javac -Xlint <yourFile>` enables all recommended warnings.

Precision

In programming, every detail counts:

- = and == have different meanings.
- Using `i` where `j` was meant can yield a hard-to-find bug.
- Declaring a variable as `int` when char was needed can cause confusing errors.
- Not considering that `n` could be `0` in `sum/n` can cause a program to fail entirely in rare but not insignificant cases.
- The difference between typing `x/2` vs. `x/2.0` can have huge impacts.
- Counting from `i` being `0` to `i < 10` vs. `i <= 10` can mean the difference between correct output and a program outputting garbage.
- Attention To Detail Test
- Attention To Detail Article

Computers and Programs

Switches

Switches use **bits** ***(binary digits)*** set to either **0** or **1** to build connections of switches called *circuits*.

Processors and Memory

To support different calculations, circuits called **processors** were created to process (aka execute) a list of desired calculations, with each calculation called an **instruction**. The instructions were specified by configuring external switches, as in the figure above. Processors used to take up entire rooms but today fit on a chip about the size of a postage stamp, containing millions or even billions of switches.

Instructions are stored in a memory. A **memory** is a circuit that can store **0**s and **1**s in each of a series of thousands of addressed locations, like a series of addressed mailboxes that each can store an envelope (the 0s and 1s). Instructions operate on data, which is also stored in memory locations as 0s and 1s.

Thus, a computer is basically a processor interacting with a memory.

- The arrangement is akin to a chef (processor) who executes instructions of a recipe (program), each instruction modifying ingredients (data), with the recipe and ingredients kept on a nearby counter (memory).

Instructions

Sample types of instructions, where `X`, `Y`, `Z`, and `num` are each an integer:

Instruction	Description
`Add X, #num, Y`	Adds data in memory location `X` to the number `num`, storing result in location `Y`.
`Sub X, #num, Y`	Subtracts `num` from data in location `X`, storing result in location `Y`.
`Mul X , #num, Y`	Multiplies data in location `X` by `num`, storing result in location `Y`.
`Div X, #num, Y`	Divides data in location `X` by `num`, storing result in location `Y`.
`Jmp Z`	Tells the processor that the next instruction to execute is in memory location `Z`.

For example, the instruction `Mul 97, #9, 98` would multiply the data in memory location `97` by the number `9`, storing the result into memory location `98`. So if the data in location `97` were `20`, then the instruction would multiply `20` by `9`, storing the result `180` into location `98`. That instruction would actually be stored in memory as **0s** and **1s**, such as `011 1100001 001001 1100010`, where `011` specifies a multiply instruction and `1100001`, `001001`, and `1100010` represent `97`, `9`, and `98` (as described previously).

- The programmer-created sequence of instructions is called a **program**, **application**, or just **app**

When powered on, the processor starts by executing the instruction at location `0`, then location `1`, then location `2`, etc. The above program performs the calculation over and over again. If location `97` is connected to external switches and location `99` to external lights, then the computer programmer could set the switches to represent a particular Celsius number, and the computer would automatically output the Fahrenheit number using the lights.

Writing Computer Programs

Originally programmers in the 1940's wrote instructions in binary, known as **machine instructions**, and a sequence of machine instructions together form an**executable program**.

Because binary is difficult to understand, programmers created programs called _assemblers___ to automatically translate human-readable instructions, such as `Mul 97, #9, 98`, known as **assembly** language instructions, into machine instructions.

In the 1960's and 1970's, programmers created **high-level languages** to support programming using formulas or algorithms.

- Early high-level languages included **FORTRAN** ***(Formula Translator)*** or **ALGOL** ***(Algorithmic Language)***

To support high-level languages, programmers created **compilers**, which are programs that automatically translate high-level language programs into executable programs.

Using this approach, executables can only run on a particular processor type (like an x86 processor); to run a program on multiple processor types, the programmer must have the compiler generate multiple executables. Some newer high-level languages like Java use an approach that allows the same executable to run on different processor types.

The approach involves having the compiler generate an executable using machine instructions of a "virtual" processor; such an executable is sometimes called **bytecode**. Then, the real processor runs a program, sometimes called a **virtual machine**, that executes the instructions in the bytecode. Such an approach may yield slower program execution, but has the advantage of portable executables.

Computer Tour

- *This section is a direct copy-paste due to the history behind everything and the length of it all*

Short History

The term computer has changed meaning over the years. The term originally referred to a person that performed computations by hand, akin to an accountant ("We need to hire a computer.") In the 1940s/1950s, the term began to refer to large machines like in the earlier photo. In the 1970s/1980s, the term expanded to also refer to smaller home/office computers known as personal computers or PCs ("personal" because the computer wasn't shared among multiple users like the large ones) and to portable/laptop computers. In the 2000s/2010s, the term may also cover other computing devices like pads, book readers, and smartphones.

The term computer even refers to computing devices embedded inside other electronic devices such as medical equipment, automobiles, aircraft, consumer electronics, military systems, etc.

In the early days of computing, the physical equipment was prone to failures. As equipment became more stable and as programs became larger, the term _software_became popular to distinguish a computer's programs from the hardware on which they ran.

Computer Components

- **Input/output devices:** A **screen** (or monitor) displays items to a user. The above examples displayed textual items, but today's computers display graphical items, too. A **keyboard** allows a user to provide input to the computer, typically accompanied by a mouse for graphical displays. Keyboards and mice are increasingly being replaced by touchscreens. Other devices provide additional input and output means, such as microphones, speakers, printers, and USB interfaces. I/O devices are commonly called *peripherals*
- **Storage:** A **disk** (aka *hard drive*) stores files and other data, such as program files, song/movie files, or office documents. Disks are *non-volatile*, meaning they maintain their contents even when powered off. They do so by orienting magnetic particles in a 0 or 1 position. The disk spins under a head that pulses electricity at just the right times to orient specific particles (you can sometimes hear the disk spin and the head clicking as the head moves). New *flash* storage devices store 0s and 1s in a non-volatile memory, rather than disk by tunneling electrons into special circuits on the memory's chip and removing them with a "flash" of electricity that draws the electrons back out.
- **Memory: RAM (random-access memory)** temporarily holds data read from storage and is designed such that any address can be accessed much faster than disk, in just a few clock ticks (see below) rather than hundreds of ticks. The "random access" term comes from being able to access any memory location quickly and in arbitrary order, without having to spin a disk to get a proper location under a head. RAM is costlier per bit than disk, due to RAM's higher speed. RAM chips typically appear on a printed-circuit board along with a processor chip. RAM is volatile, losing its contents when powered off. Memory size is typically listed in bits or in bytes, where a byte is 8 bits. Common sizes involve megabytes (million bytes), gigabytes (billion bytes), or terabytes (trillion bytes).
- **Processor:** The **processor** runs the computer's programs, reading and executing instructions from memory, performing operations, and read-

ing/writing data from/to memory. When powered on, the processor starts executing the program whose first instruction is (typically) at memory location 0. That program is commonly called the **BIOS (basic input/output system)**, which sets up the computer's basic peripherals. The processor then begins executing a program called an operating system (OS). The **operating system** allows a user to run other programs and interfaces with the many other peripherals. Processors are also called CPUs (central processing units) or microprocessors (a term introduced when processors began fitting on a single chip, the "micro-"suggesting something small). Because speed is so important, a processor may contain a small amount of RAM on its own chip, called **cache** memory, accessible in one clock tick rather than several, for maintaining a copy of the most-used instructions/data.

- **Clock:** A processor's instructions execute at a rate governed by the processor's **clock**, which ticks at a specific frequency. Processors have clocks that tick at rates such as 1 MHz (1 million ticks/second) for an inexpensive processor ($1) like those found in a microwave oven or washing machine, to 1 GHz (1 billion ticks/second) for costlier ($10-$100) processors like those found in mobile phones and desktop computers. Executing about 1 instruction per clock tick, processors thus execute millions or billions of instructions per second.

Computers typically run multiple programs simultaneously, such as a web browser, an office application, a photo editing program, etc. The operating system actually runs a little of program A, then a little of program B, etc., switching between programs thousands of times a second.

After computers were invented and occupied entire rooms, engineers created smaller switches called **transistors**, which in 1958 were integrated onto a single chip called an **integrated circuit**, or IC. Engineers continued to make transistors smaller, leading to **Moore's Law**: the doubling of IC capacity roughly every 18 months, which continued for several decades.

Note: Moore actually said every 2 years. And the actual trend has varied from 18 months. The key is that doubling occurred roughly every two years, causing much improvement over time. Intel: Moore's Law.

By 1971, Intel produced the first single-IC processor named the 4004, called a *microprocessor* (*micro-* suggesting something small), having 2,300 transistors. New, more powerful microprocessors appeared every few years, and by 2012, a single IC had several billion transistors containing multiple processors (each called a *core*).

- ***A side note:*** A common way to make a PC faster is to add more RAM. A processor spends much of its time moving instructions/data between memory and storage, because not all of a program's instructions/data may fit in memory—akin to a chef who spends most of his/her time walking back and forth between a stove and pantry. Just as adding a larger table next to the stove allows more ingredients to be kept close by, a larger memory allows more instructions/data to be kept close to the processor. Moore's Law results in RAM being cheaper a few years after buying a PC, so adding RAM to a several-year-old PC can yield good speedups for little cost.

Exploring Further

- Video: Where's the disk/memory/processor in a desktop computer (20sec)
- Link: What's Indide a Computer (HowStuffWorks.com)
- Video: How Memory Works (1:49)
- Link: How Microprocessors Work (HowStuffWorks.com)

Language History

- *This section is a direct copy-paste due to the history behind everything and the length of it all*

In 1978, Brian Kernighan and Dennis Ritchie at AT&T Bell Labs (which used computers extensively for automatic phone call routing) published a book describing a new high-level language with the simple name **C**, being named after another language called B (whose name came from a language called BCPL). C became the dominant programming language in the 1980s and 1990s.

In 1985, Bjarne Stroustrup published a book describing a C-based language called **C++**, adding constructs to support a style of programming known as object-oriented programming, along with other improvements. The unusual ++ part of the name comes from ++ being an operator in C that increases a number, so the name C++ suggests an increase or improvement over C.

In 1991, James Gosling and a team of engineers at Sun Microsystems (acquired by Oracle in 2010) began developing the **Java** language with the intent of creating a language whose executable could be ported to different processors, with the first public release in 1995.

The language had a C/C++ style and for portability reasons was designed to execute on a virtual machine. Java was initially intended to be run on consumer appliances like interactive TVs. Web browsers like Netscape Navigator began providing support for running Java programs within the browser, bringing much attention to the language. The Java language continues to evolve for the programming of traditional computers and consumer devices. Java should not be confused with JavaScript, which is an entirely different language used for developing web applications that was named similarly.

A January 2022 survey ranking languages by their popularity, based on programming related searches using popular search engines, yielded the following:

Language	Percentage
Python	13.58%
C	12.44%
Java	10.66%
C++	8.29%
C#	5.68%
Visual Basic	4.74%
JavaScript	2.09%
Assembly language	1.85%
SQL	1.80%
Swift	1.41%

Precision, logic, and computational thinking

Many people find that programming encourages precise, logical thought that can lead to better writing and speaking, clearer processes, and more. The thought processes needed to build correct, precise, logical programs is sometimes called **computational thinking** and has benefits beyond programming.