CS102 Unit 0c – Programming Languages and C++ Program Structure

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Unit Objectives

- Define: **algorithm**, **syntax**, and **semantics**
- Know that statements in a program execute sequentially by default
- Know the basic parts of a C++ program
  - Inclusion of library "headers"
  - Comments
  - Code is partitioned into **functions**
  - main() function as the starting point

ALGORITHMS & PROGRAMMING LANGUAGES

Humans and Computers

- Humans understand instructions differently than computers
- Humans easily tolerate ambiguity and abstract concepts using context to help.
  - "Add a pinch of salt." How much is a pinch?
  - "Steph Curry can shoot the lights out."
- Computers must be **precise**, only executing well-defined instructions (**no ambiguity**) and operating on digital information which is finite and discrete (a fixed number of options)

Algorithms

- Algorithms are at the heart of computer systems, both in HW and SW
  - They are fundamental to Computer Science and Computer Engineering
- Informal definition
  - **An algorithm is a precise way to accomplish a task or solve a problem**
- A more formal definition:
  - An ordered set of
  - unambiguous,
  - executable steps that defines
  - a terminating process
- Examples: What is the algorithm for
  - Brushing your teeth?
  - Calculating your GPA?

```
function enEdition(){
    /* Ne rien faire mode edit + preload */
    if( encodeURIComponent(document.location
turn;
    // /&preload=/

    if ( !wgPageName.match(/Discussion.*\/Tra
    var diff = new Array();
    var status; var pecTraduction; var pecRe
    var avancementTraduction; var avancementT
```

Software

Hardware

Algorithm Representation

- An algorithm is NOT a program or programming language
- Just as a story may be represented as a book, movie, or spoken by a story-teller, an algorithm may be represented in many ways
  - Flow chart
  - Pseudocode (English-like syntax using primitives that most programming languages would have)
  - A specific program implementation in a given programming language
- The skill we REALLY want to help you build is **algorithmic thinking** (i.e. developing algorithms)

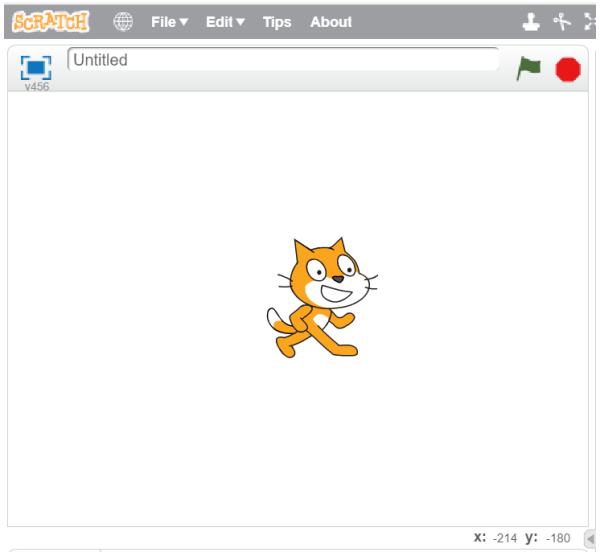
Syntax and Semantics

- Programming languages have **syntax** and **semantics**
- **Syntax**: refers to the rules of a language for how it will be expressed and parsed (decomposed)
  - Specific to the language
- **Semantics**: refers to the meaning of what is written
  - Often transcends the language (same concept in many languages)
- Example: A sentence
  - The **syntax** refers to the proper **grammatical rules** for writing a sentence: *capitalize the first word, have a subject and verb, ending with a period, etc.*
  - The **semantics** refer to the **meaning** conveyed by the sentence
- C++ Code Example
  - `if ( <condition> ) { <action> }` is the syntax.
  - The semantics (meaning) is "the *action* will only be performed if *condition* is true"

CODE ORGANIZATION AND SEQUENCE OF EXECUTION

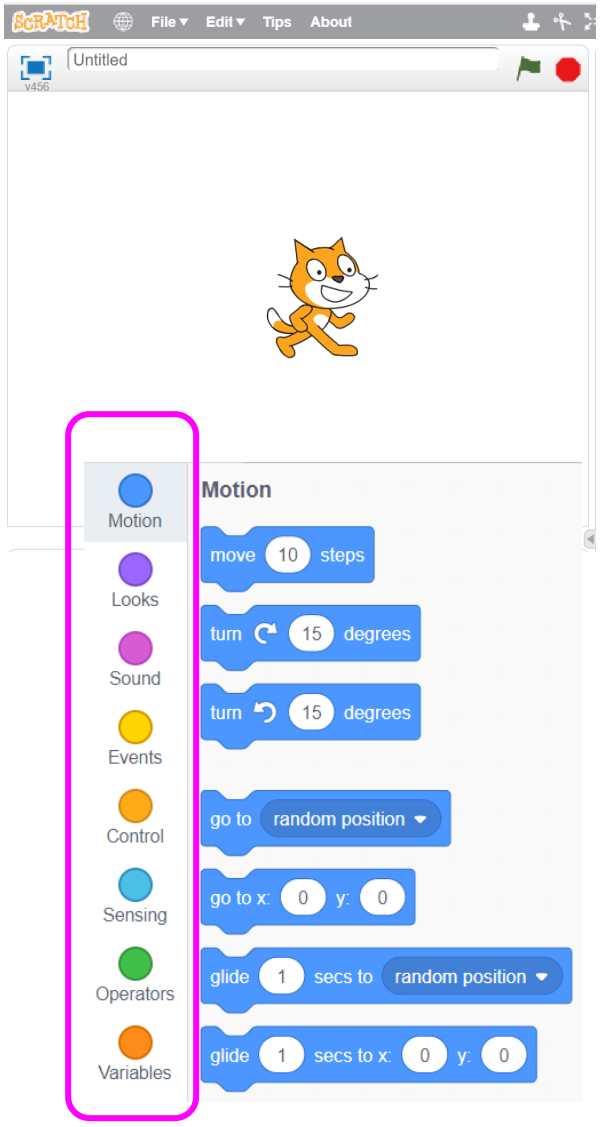
Sequence & Executability

- Let's learn a bit more about program execution by using another language named Scratch
  - http://scratch.mit.edu
- Write a Scratch program to walk forward, turn right, then walk forward again
- Remember computers need executable steps
  - How far forward?
  - Turn right by how much?



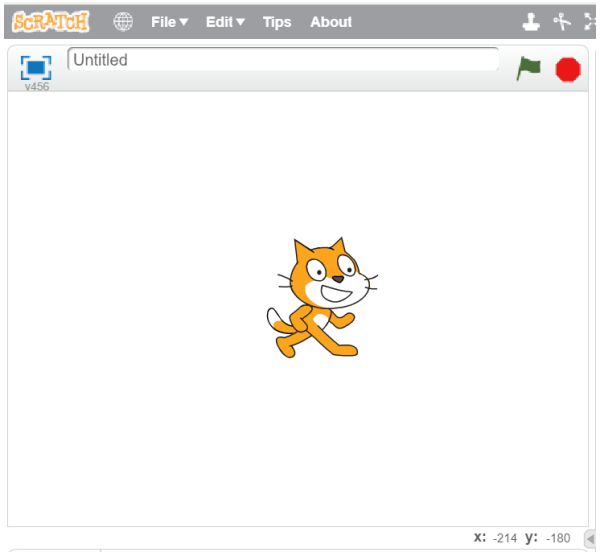
Executability

- Scratch handles the syntax by providing a **menu** of specific "blocks" that define what the language allows you to do
  - Anything you want to do that doesn't have a specific block, requires you to compose use multiple blocks
  - Some blocks have certain aspects you can set to control their behavior.
- Go to the Scratch website, click on Create, and close the tutorial
- Write a Scratch program to walk forward, turn right, then walk forward again
- Remember computers and algorithms need **executable** steps
  - How far forward?
  - Turn right by how much?



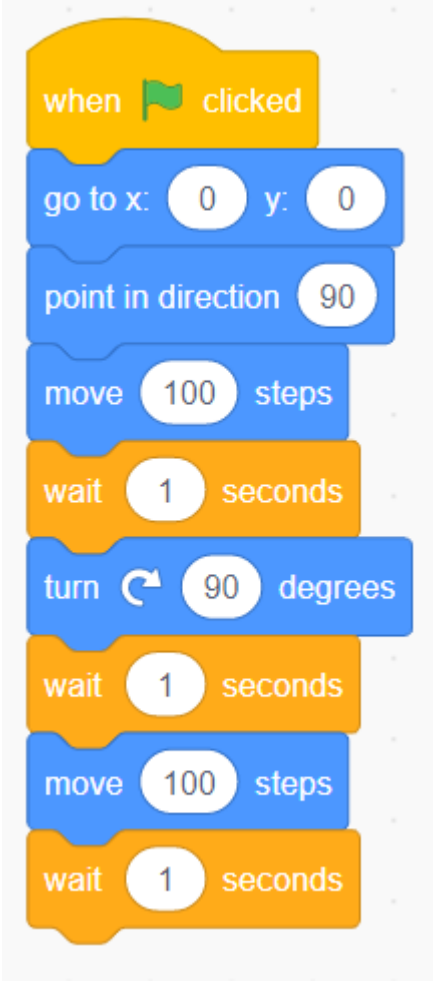
Sequence & Executability

- You must compose a program from the "menu" of available blocks
- Create the program shown to the right and then click the green flag to the left of the red stop sign
  - What happens?
- Click the green flag again
  - What happens?



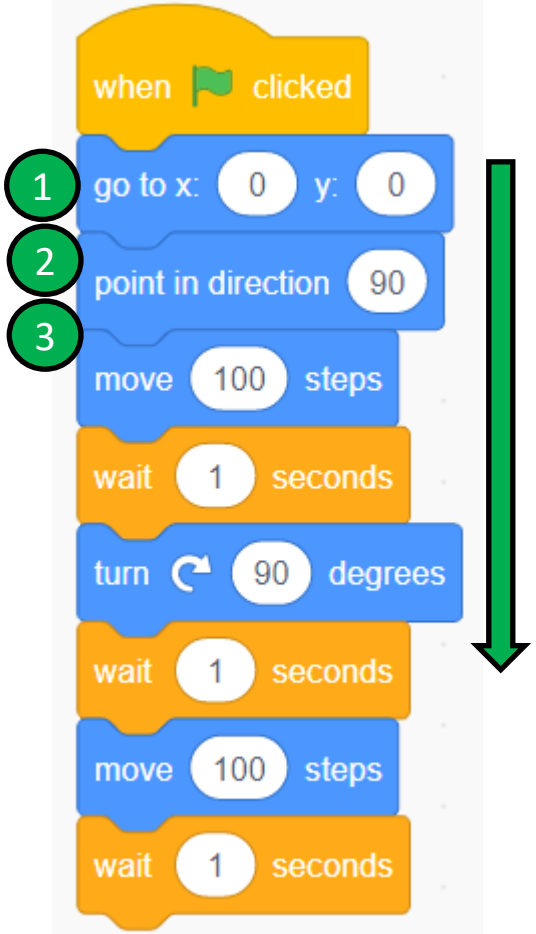
Explicit Content

- Computers do only what you tell them, no more, no less
- What additional details might we want to instruct the computer?
  - Where to start and what direction to face?
  - To provide some delay between steps
    - Remember computers execute code very quickly compared to what a human can see



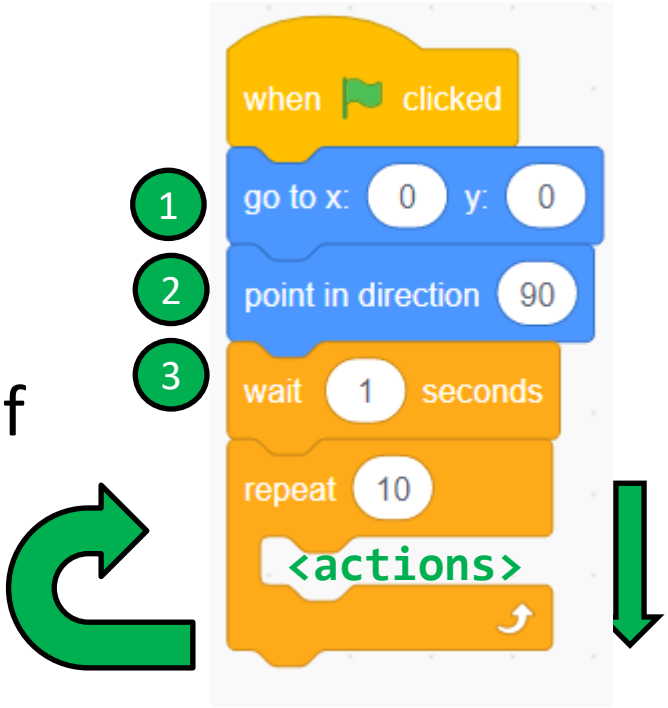
Big Idea: Sequential Execution

- Notice…
  - Program is executed 1 operation at a time in sequential fashion
  - Each operation is ordered (a definite first, second, third, … operation)



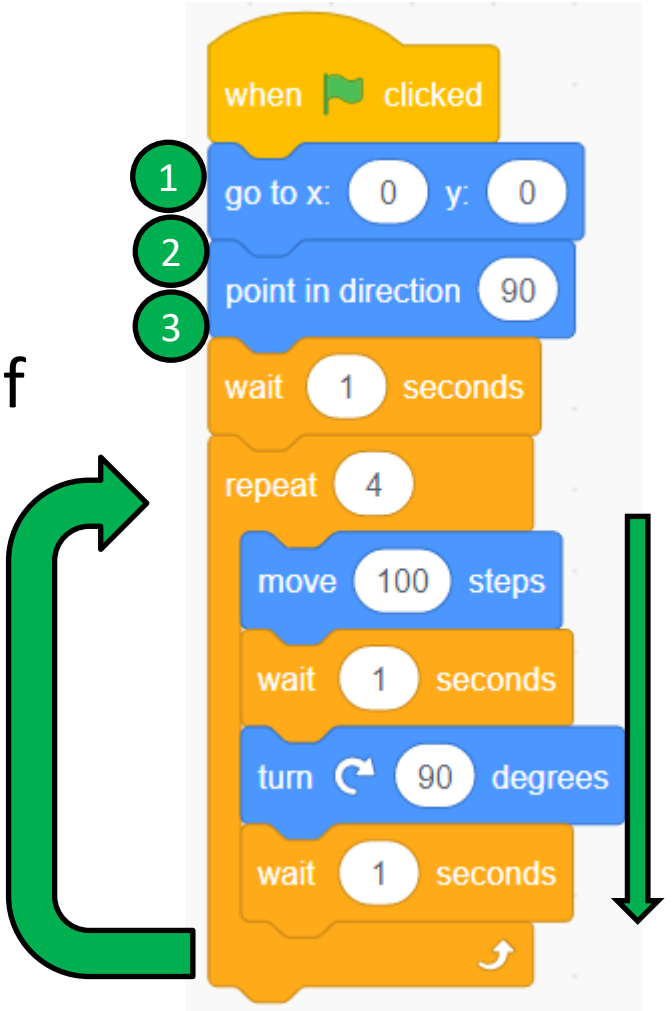
Repetition 1

- Computers are good at repeating tasks quickly
- If we can find repeated structure, we can use a **loop** to **repeat** a set of actions multiple times
- What actions can we repeat and how many times to have our cat friend walk in a square?



Repetition 2

- Computers are good at repeating tasks quickly
- If we can find repeated structure, we can use a **loop** to **repeat** a set of actions multiple times

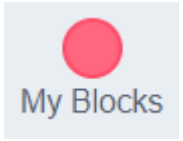


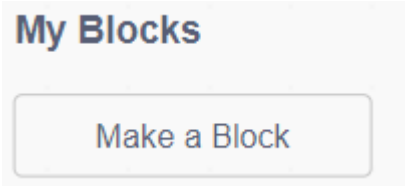
Only if time allows!

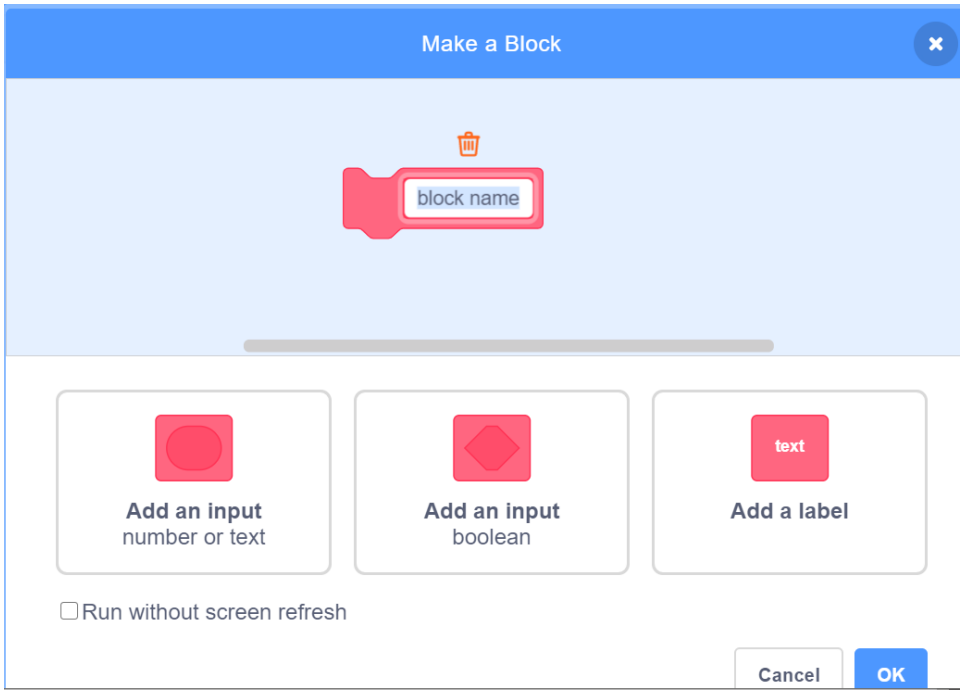
GROUPING CODE IN FUNCTIONS (AKA BLOCKS)

Organizing Code - Functions

- Another way to allow reuse and easy modification is to give a name to sequence of code/actions
  - Wherever we use the name, the associated sequence of code/actions will be execute
- Most programming languages call these functions, methods, procedures, subroutines, etc.
- Scratch calls them "Blocks"
- Create a block named: **WalkForwardAndTurn**

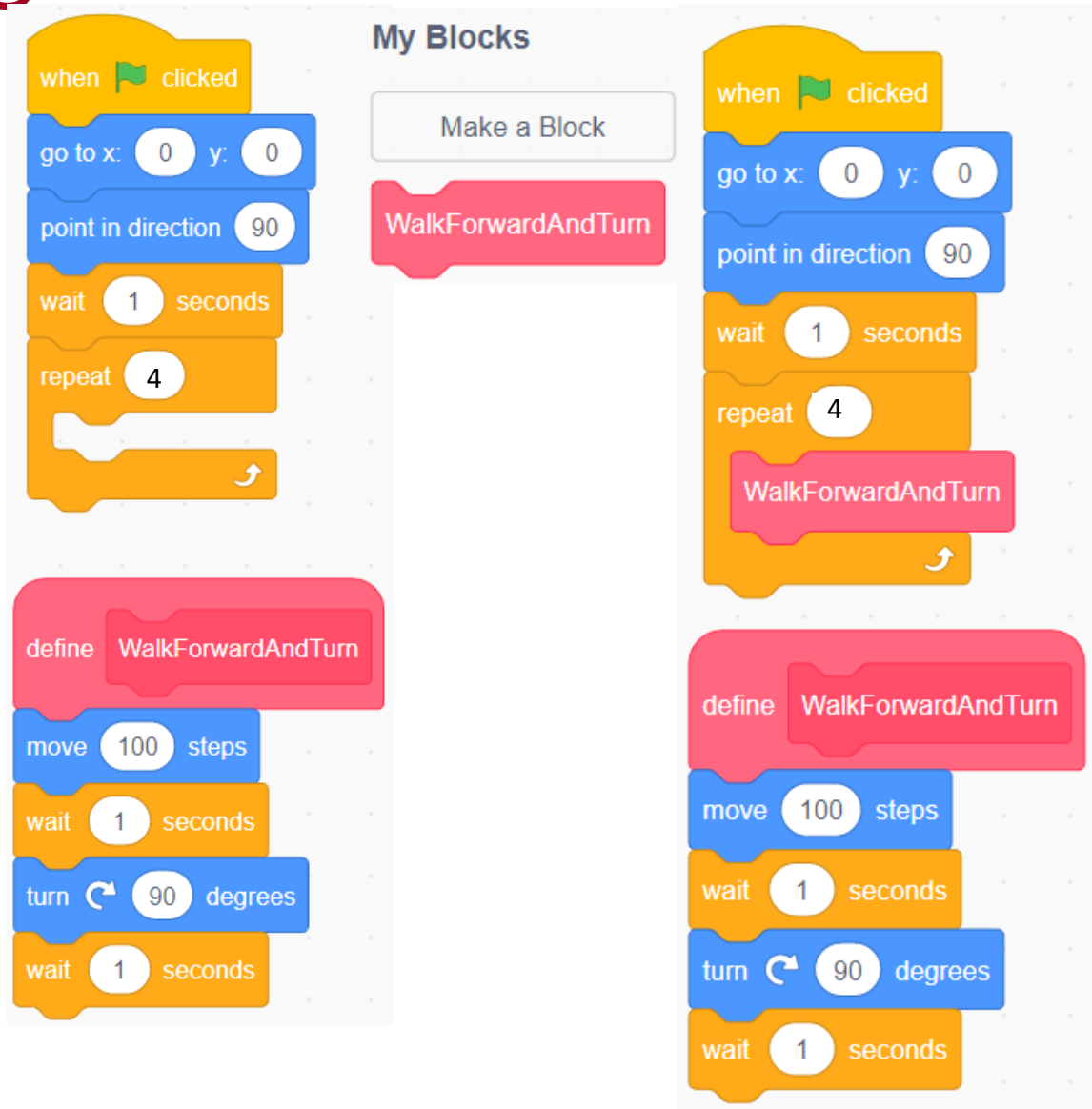






Organizing Code - Functions

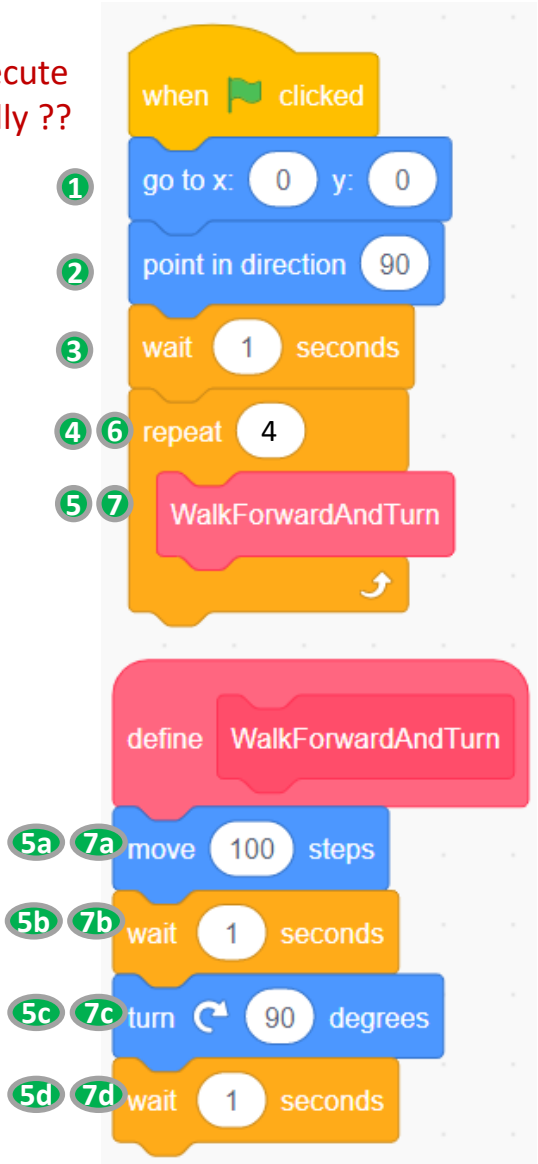
- We can take the actions in our loop and drag them to the definition of **WalkForwardAndTurn**
- Then click on "My Blocks", find your new block and drag it into the repeat loop



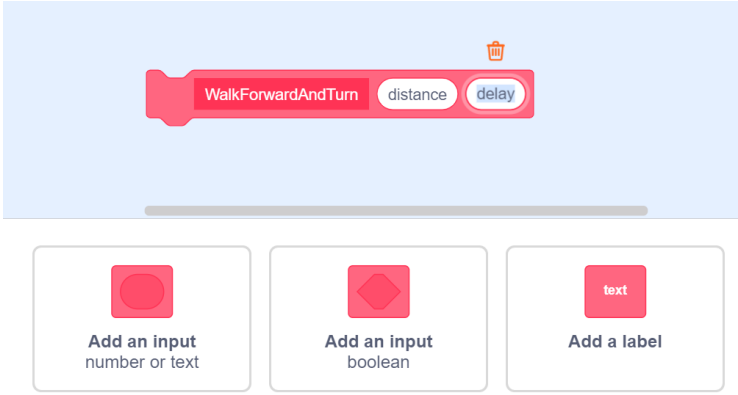
Sequence of Execution With Functions

- We said we execute sequentially, but with loops and functions is our code still executed sequentially (top-down)?
- No.
  - Loops cause execution to go back and repeat code and
  - Functions may cause us to jump to a new set of actions, execute them, and the return back and resume the main program

Do we execute Sequentially ??



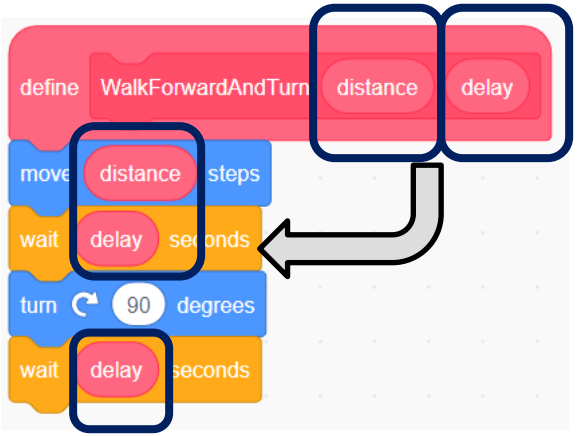
Functions & Parameters/Arguments



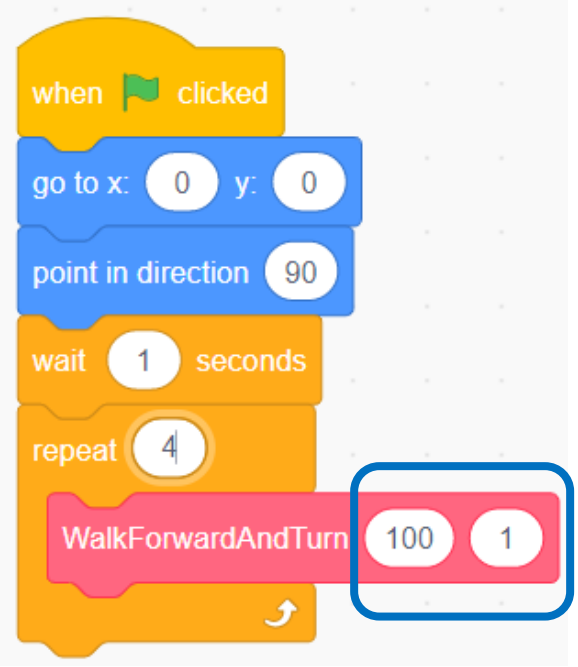
- Our function "DelayedMove" is useful for the simple task we gave you to implement, but what if I wanted to walk in a **rectangle**?
  - We now need to walk different lengths
- **Q:** What might make it more useful and "general" so that we could reuse it in the future more easily?
- **A:** The ability to generalize how many steps to take and how long to wait might be helpful
  - We call these "input parameters"
- Let's allow different values of steps and the delay to be input.
  - Right click on the WalkForwardAndTurn and choose Edit
  - Click on "Add an Input (number or Text)" once and give the newly appearing box the name: **distance** and the click on "Add an Input" again and give the new box the name: **delay**

Parameters/Arguments

- Back in the main window, two new entries "distance" and "delay"
- Drag these in place of the constants (100 or 1) in the move / wait blocks



- Back in the main program, fill in the two text boxes with 100 and 1



- How could you modify the main program only to make the cat walk in a rectangle of 200 wide and 100 long?

FIRST C++ PROGRAMS

C/C++ Program Format/Structure

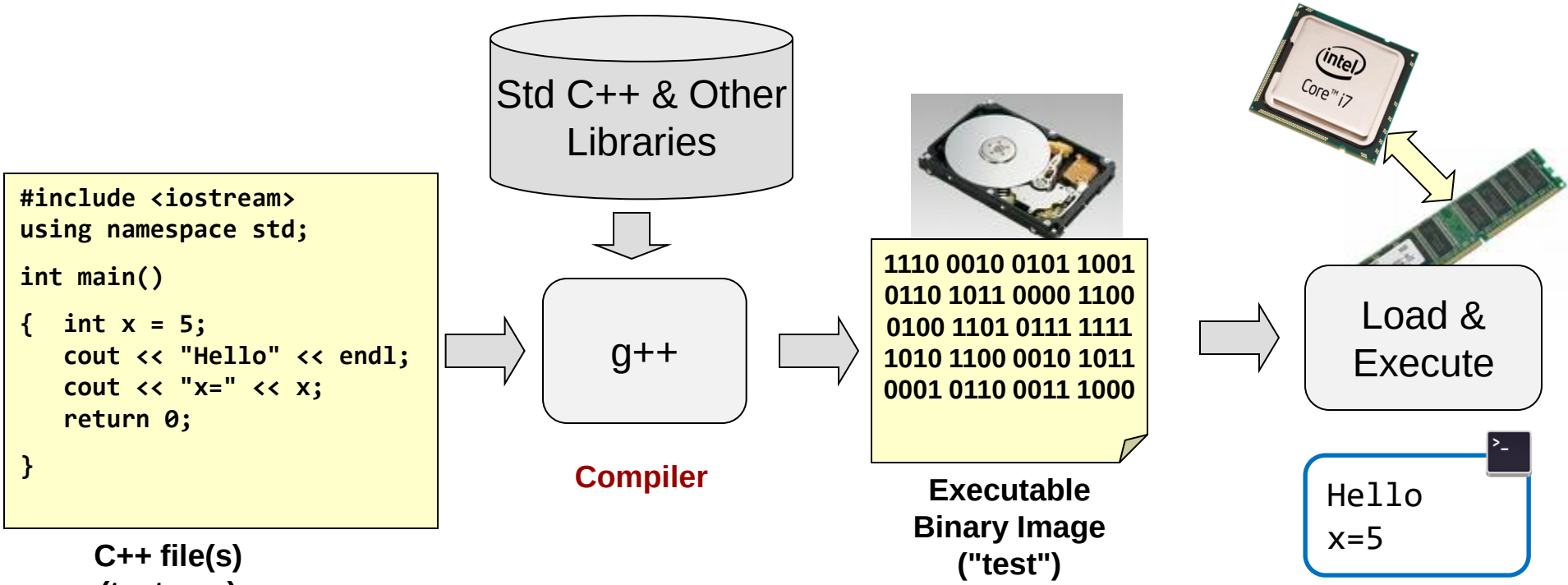
- Comments
  - Anywhere in the code
  - Multiline C-Style => `/*` and `*/`
  - Single line C++ Style => `//`
- Include Libraries and Compiler Directives
  - #include's tell the compiler what other library functions you plan on using
  - `using namespace std;` -- Just do it for now!
- main() function 

  - Starting point of execution for the program
  - All code/statements in C must be inside a function
  - Statements execute sequentially (one after the next) and end with a semicolon (;)
  - `main()` ends with a `return 0;` statement
- Other functions
  - `printName()` is a function that can be "called"/"invoked" from main or any other function

```
/* Anything between slash-star and
star-slash is ignored even across
multiple lines of text or code */

// Anything after "//" is ignored on a line

// #includes allow access to library functions
#include <iostream>
#include <cmath>
using namespace std;

// Code is organized into units called functions
void printName()
{
  cout << "Tommy Trojan" << endl;
}

// Execution always starts at the main() function
int main()
{
  cout << "Hello: " << endl;
  printName();
  printName();
  double y = sin(M_PI/4);
  cout << y << endl;
  return 0;
}
```

```
Hello
Tommy Trojan
Tommy Trojan
0.7071
```

Software Process



1. Edit & write code
2. Compile & fix syntax (compile-time) errors
3. Load & run the executable program looking for and fixing semantic (runtime) errors

Try it

- Go to http://cpp.sh or EdStem Workspaces
- Enter this program to print "Hello!" **five** times

```
#include <iostream>
using namespace std;
int main()
{
  for(int i=0; i < 5; i++) {
    cout << "Hello!" << endl;
  }
  return 0;
}
```

C++ syntax requires statement to end with a semicolon (;) and grouped by curly braces { }. Removing one would lead to a syntax error.

- Introduce some syntax errors
- Introduce a semantic error

A semantic error is when I tell the computer to do the wrong thing but it still meets the correct syntax. Change "i=0" to "i=1" and see it print only 4 times rather than the desired 5.

Formatting/Spacing and C++

- The C++ compiler does NOT care about spaces, tabs, and newlines.
- The following two programs both compile and run equivalently.

```
#include <iostream>
using namespace std;
int main()
{
  for(int i=0; i < 5; i++) {
    cout << "Hello!" << endl;
  }
  return 0;
}
```

```
#include <iostream>
using namespace std;
int
main(
            )  {
  for(int i=
  0; i <                5; i++)
{ cout << "Hello!" << endl; } return


                  0             ;   }
```

- There is even an annual contest to see who can write the most obfuscated but legal C program:
  - https://www.ioccc.org/years.html and https://www.ioccc.org/2020/yang/prog.c