Introduction to C++ Loops

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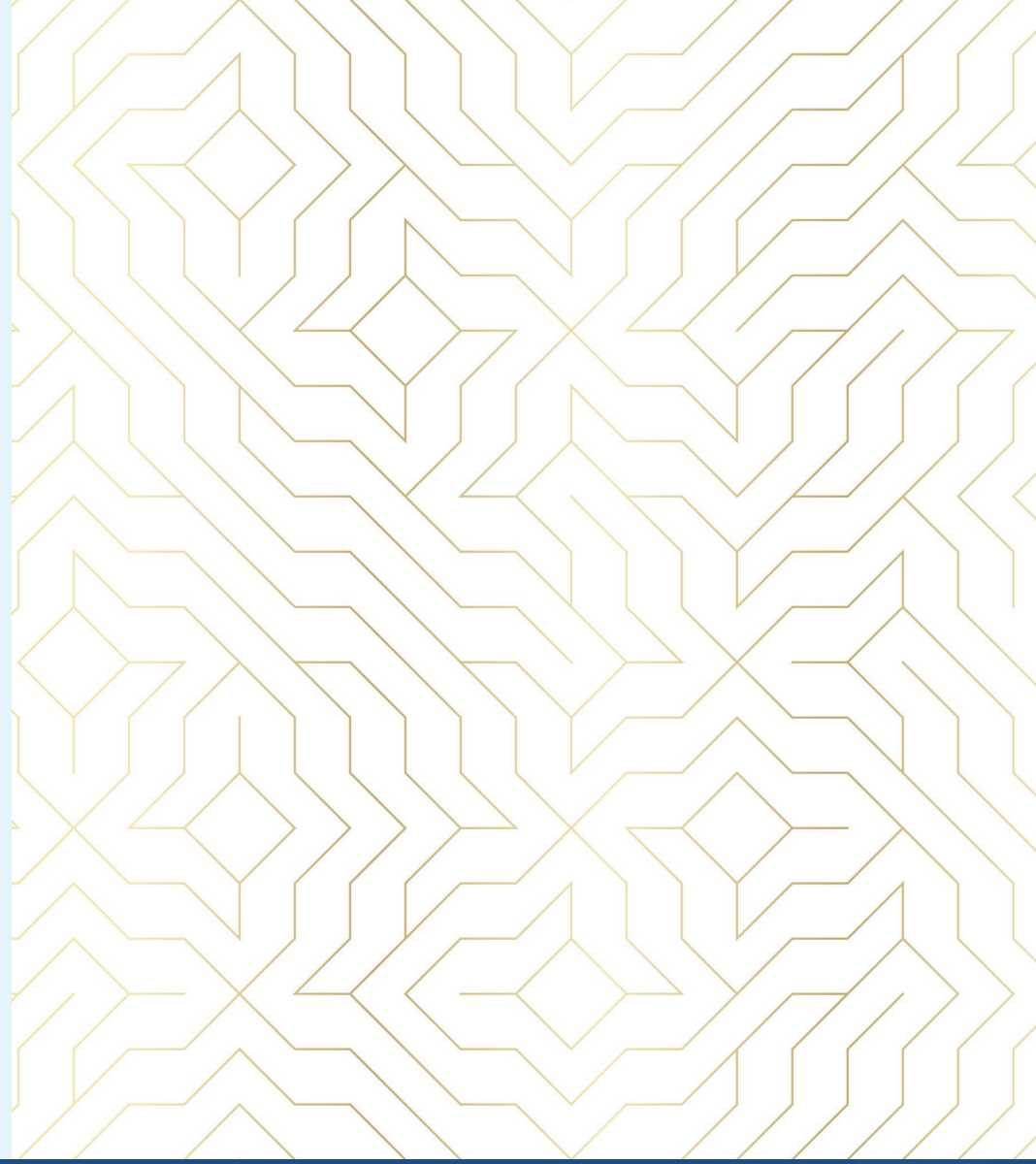
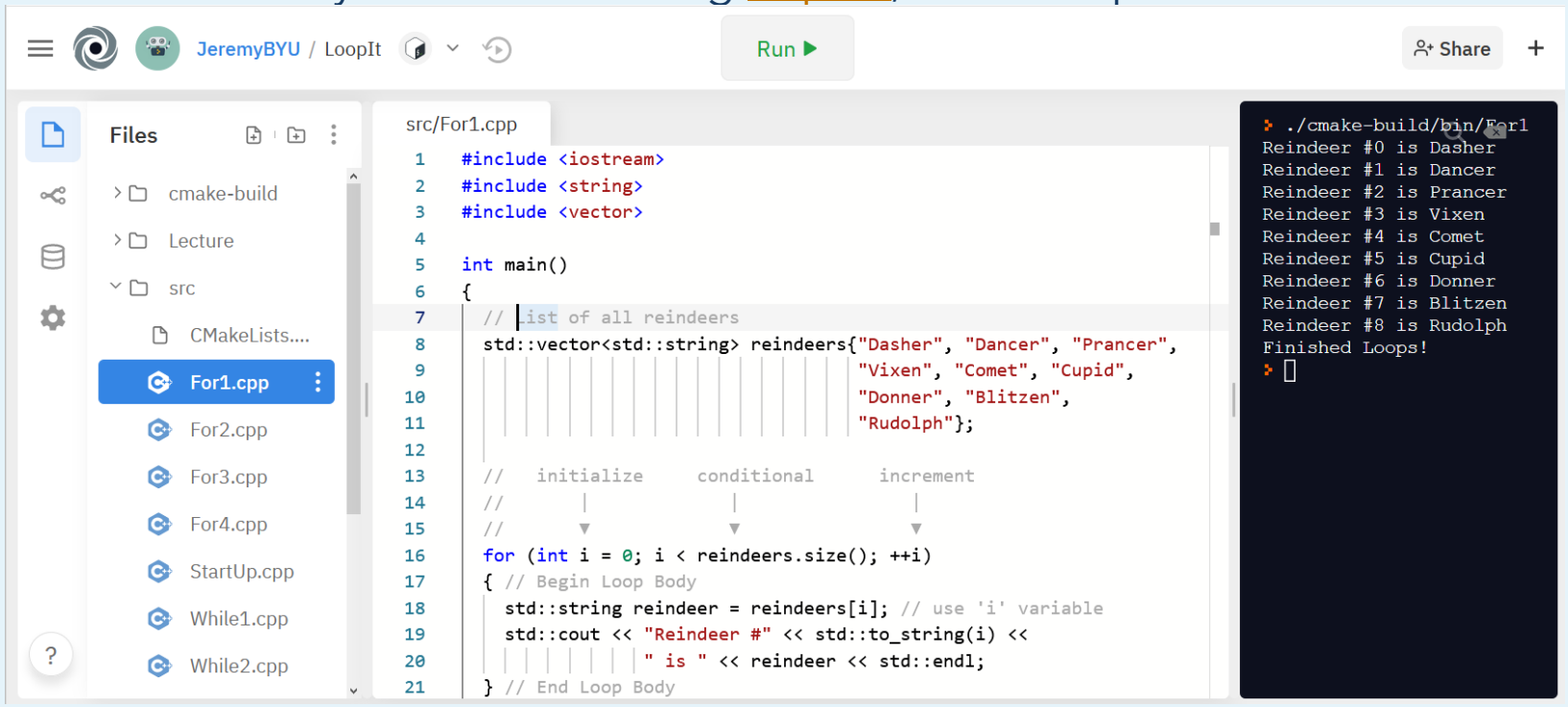


About Me

- Chemical Engineering and Computer Science @ Brigham Young University
- 3 years as a control systems engineer @ Valero
- 5th Year PhD Robotics @ University of Michigan
- Research focused on urgent landing for Unmanned Aerial Vehicles
- Love C++ and Python!

Getting Started

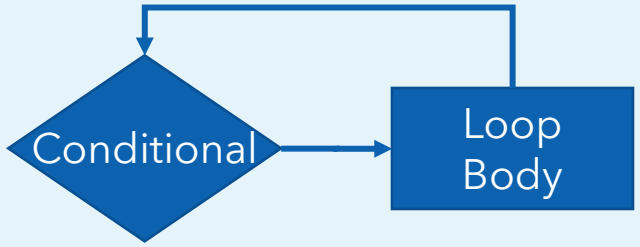
- Entire lecture and source code are hosted on Github - https://github.com/JeremyBYU/LoopIt
- Examples can be run in your browser using Repl.it , C++ compiler and editor



- Lecture assumes students have a basic knowledge of basic C++ datatypes and declaring variables
  - bool, int, string, vector

What We Are Learning - Loops

- Often need to repeat a body of code when programming
- C++ has two main types of loops: for & while



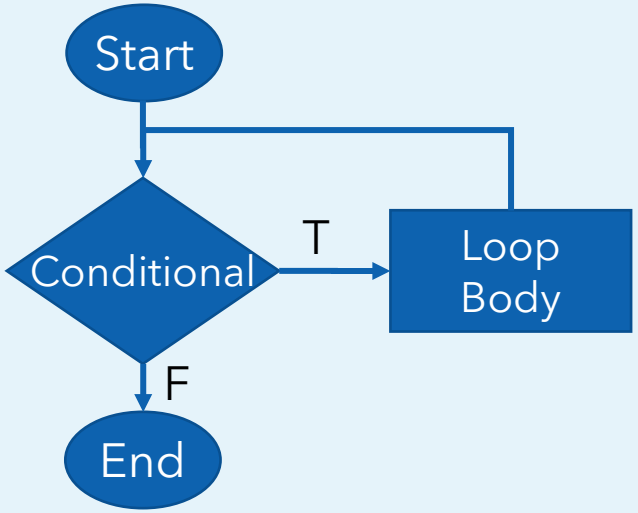
Q: What is a Conditional?

A: Something that evaluates to either true (T) or false (F)

- Keywords we will be learning: for, while, do, break, continue
- Will *not* learn about goto flow control
- At the end we will learn about modern C++ for loops
- Examples are not meant to be *optimal or efficient;* demonstrate principles

While Loops - Basic

- Loop forever until a condition is met



Condition Variable

While Loop Keyword

Loop Body

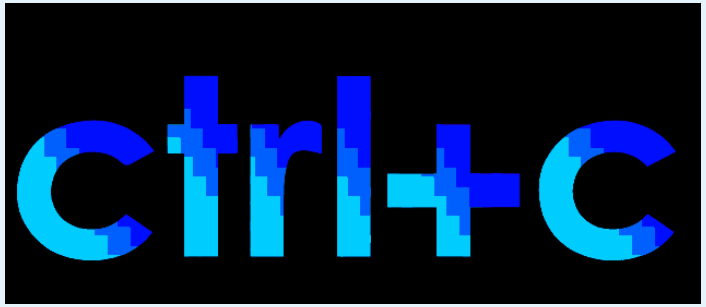
Update Variable

src/While1.cpp

```
1   #include <iostream>
2   #include <string>
3   int main()
4   {
5
6     bool repeat = true; // condition variable
7     std::string input;  // user input variable
8
9     //  conditional
10    //      |
11    //      ▼
12    while(repeat)
13    { // Begin Loop Body
14      std::cout << "Loop execututed. Repeat? (y/n): ";
15      std::getline (std::cin, input);
16      repeat = input == "y";
17    } // End Loop Body
18    std::cout << "Finished Loops!\n";
19  }
```

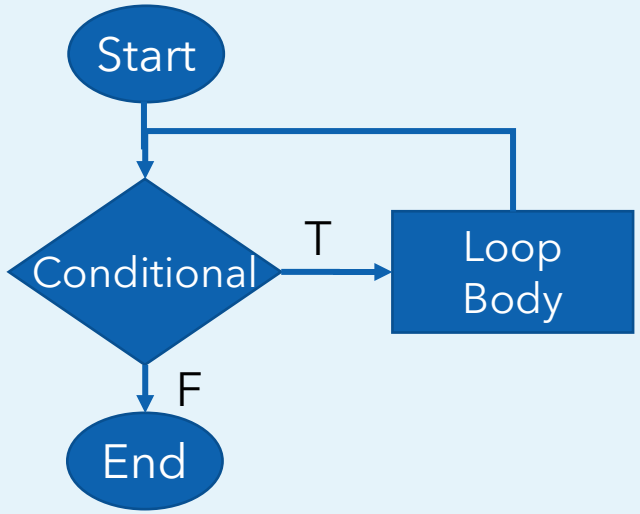
Example Program Output:

```
./cmake-build/bin/While1
Loop execututed. Repeat? (y/n): y
Loop execututed. Repeat? (y/n): y
Loop execututed. Repeat? (y/n): y
Loop execututed. Repeat? (y/n): n
Finished Loops!
```



While Loops – Break Statement

- You can also use the break keyword to exit a loop



Condition Statement

Exit Loop

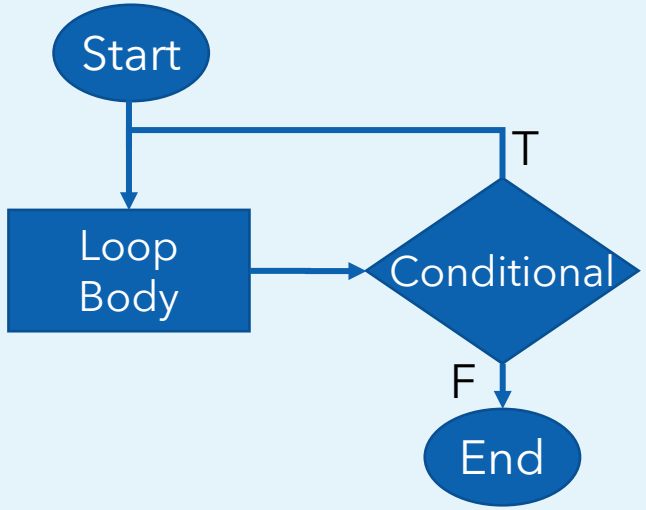
src/While2.cpp

```
1   #include <iostream>
2   #include <string>
3   int main()
4   {
5     std::string input;  // user input variable
6
7     while(true)
8     { // Begin Loop Body
9       std::cout << "Loop execututed. Repeat? (y/n): ";
10      std::getline (std::cin, input);
11      if (input != "y")
12      {
13        // Break out of loop
14        break;
15      }
16
17    } // End Loop Body
18    std::cout << "Finished Loops!\n";
19  }
```

- When to use while loops?
  - Don't know how many times to repeat code
  - Infinitely repeating until user input exit
  - Often used for game loops: Get Input, Update Game, Render

While Loops – Do While

- Do while loops execute Loop Body *first,* then conditional



Condition Variable

do keyword

Update Variable

Condition Statement

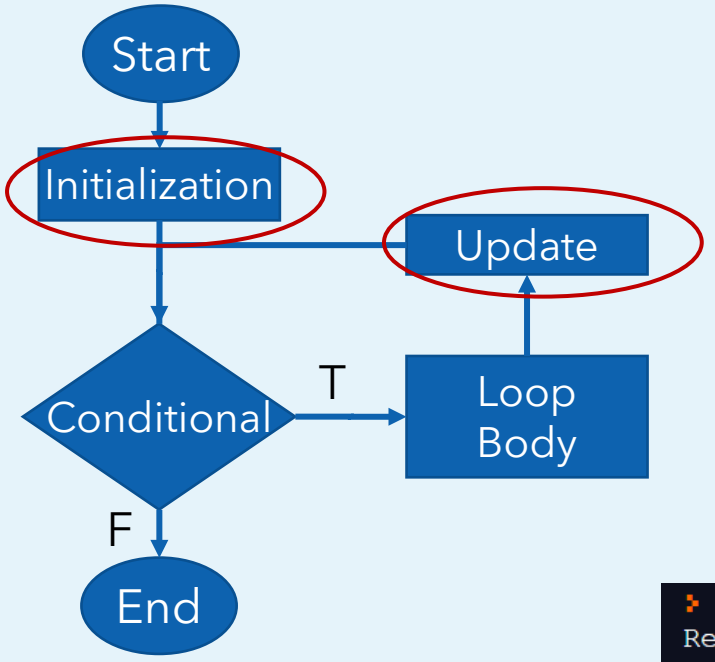
src/While3.cpp

```
1   #include <iostream>
2   #include <string>
3   int main()
4   {
5
6     bool repeat = false; // condition variable
7     std::string input;  // user input variable
8
9     do
10    { // Begin Loop Body
11      std::cout << "Loop execututed. Repeat? (y/n): ";
12      std::getline (std::cin, input);
13      repeat = input == "y";
14    } // End Loop Body
15    while(repeat);
16    //      ▲
17    //      |
18    //  conditional
19    std::cout << "Finished Loops!\n";
20  }
```

- It doesn't matter that repeat is set to False in Line 6
- Loop Body is executed at *least once*

For Loops – Holiday Special

- For loops have an **initialization**, **conditional**, and **update**



List of Reindeers

Conditional Statement

Update Statement

Use index

src/For1.cpp

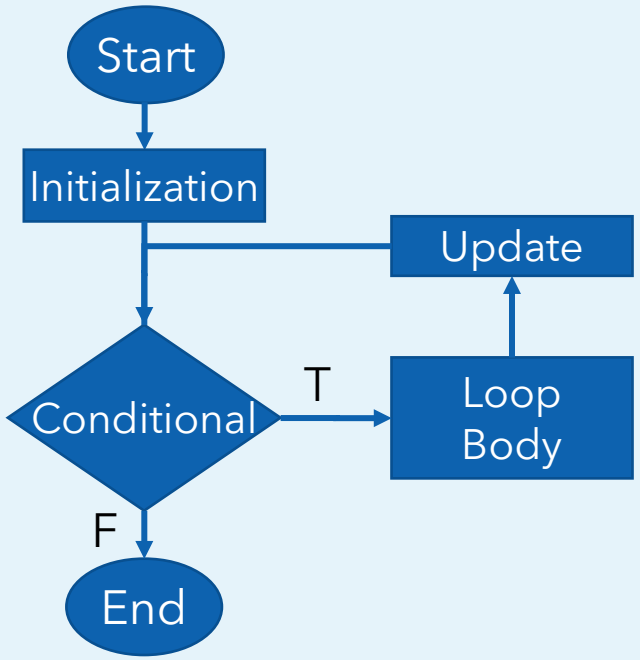
```
1   #include <iostream>
2   #include <string>
3   #include <vector>
4
5   int main()
6   {
7     // List of all reindeers
8     std::vector<std::string> reindeers{"Dasher", "Dancer", "Prancer",
9                                        "Vixen", "Comet", "Cupid",
10                                       "Donner", "Blitzen",
11                                       "Rudolph"};
12
13    //   initialize     conditional      increment
14    //        |              |               |
15    //        ▼              ▼               ▼
16    for (int i = 0; i < reindeers.size(); ++i)
17    { // Begin Loop Body
18      std::string reindeer = reindeers[i]; // use 'i' variable
19      std::cout << "Reindeer #" << std::to_string(i) <<
20                   " is " << reindeer << std::endl;
21    } // End Loop Body
22    std::cout << "Finished Loops!\n";
23  }
```

Example Program Output:

```
./cmake-build/bin/For1
Reindeer #0 is Dasher
Reindeer #1 is Dancer
Reindeer #2 is Prancer
Reindeer #3 is Vixen
Reindeer #4 is Comet
Reindeer #5 is Cupid
Reindeer #6 is Donner
Reindeer #7 is Blitzen
Reindeer #8 is Rudolph
Finished Loops!
```

For Loops – Continue Statement

- You can **skip** execution of remaining loop with continue



Conditional **in** Loop Body

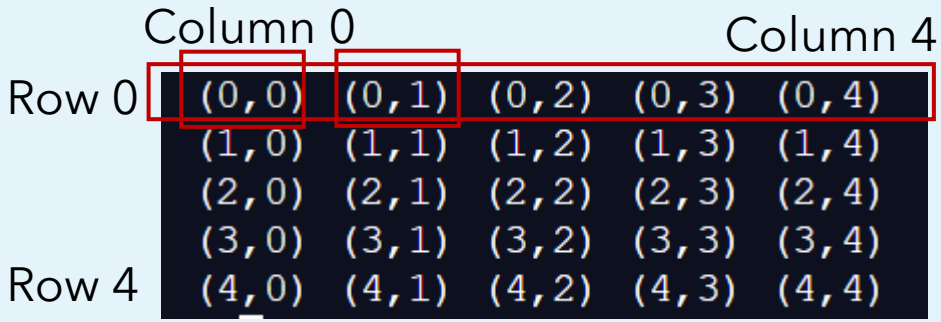
```
 5  int main()
 6  {
 7    // List of all reindeers
 8    std::vector<std::string> reindeers{"Dasher", "Dancer", "Prancer",
 9                                       "Vixen", "Comet", "Cupid",
10                                       "Donner", "Blitzen",
11                                       "Rudolph"};
12
13    //   initialize     conditional      increment
14    //        |              |                |
15    //        ▼              ▼                ▼
16    for (int i = 0; i < reindeers.size(); ++i)
17    { // Begin Loop Body
18      std::string reindeer = reindeers[i]; // use 'i' variable
19      if (reindeer == "Cupid")
20      {
21        // Skip this reindeer, don't print name
22        continue;
23      }
24      std::cout << "Reindeer #" << std::to_string(i) <<
25                   " is " << reindeer << std::endl;
26    } // End Loop Body
27    std::cout << "Finished Loops!\n";
28  }
```

Example Program Output:

```
./cmake-build/bin/For2
Reindeer #0 is Dasher
Reindeer #1 is Dancer
Reindeer #2 is Prancer
Reindeer #3 is Vixen
Reindeer #4 is Comet
Reindeer #6 is Donner
Reindeer #7 is Blitzen
Reindeer #8 is Rudolph
Finished Loops!
```

Nested For Loops

- For loops can be *nested*, a loop inside a loop
- Two for loops: **outer** & **inner**
- Example printing a square
- Outer loop = rows, Inner loop = columns



src/For4.cpp

```
1   #include <iostream>
2   #include <string>
3
4   int main()
5   {
6     const int rows = 5;
7     const int cols = 5;
8     // Outer For Loop
9     for (int i = 0; i < rows; ++i)
10    {
11      // Inner for loop
12      for (int j = 0; j < cols; ++j)
13      {
14
15        std::cout << "(" << i << "," << j << ")" << " ";
16      }
17      std::cout << std::endl;
18    }
19  }
```

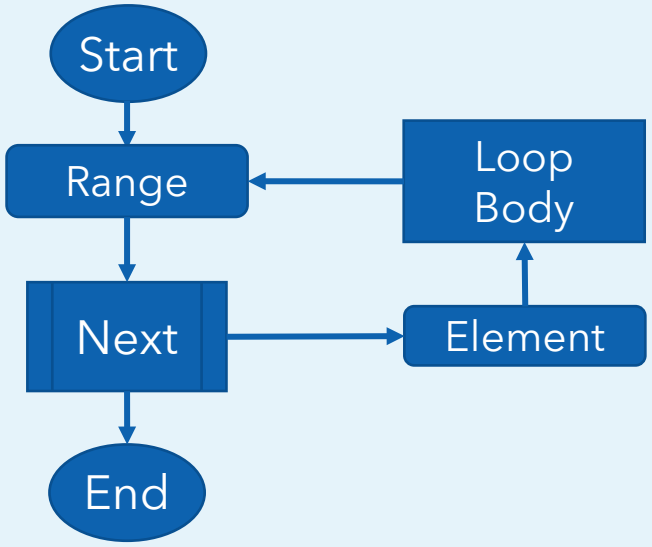
Variable 'i' stays constant in inner loop

Modern C++

- C++ is a language with a formal specification. However, it is a *living* language!
  - C++98, C++03, **C++11**, C++14, C++17, C++20
  - Strong backwards compatibility!
- C++11 introduced many enhancements that greatly improved code quality and efficiency
- C++11 and after is considered ***Modern C++***
- We will review a new for loop constructs introduced in C++11: Range-based for loops
- These don't replace previously discussed patterns; they simply augment them
  - Specifically meant for ranges, aka sequences/lists

Range-based For Loop

- Execute loop body for each *element* inside *Range*
- A *Range* is a sequence of elements, e.g., [1, 2, 3]



src/For3.cpp

```
1   #include <iostream>
2   #include <string>
3   #include <vector>
4
5   int main()
6   {
7     // List of all reindeers
8     std::vector<std::string> reindeers{"Dasher", "Dancer", "Prancer",
9                                        "Vixen", "Comet", "Cupid",
10                                       "Donner", "Blitzen",
11                                       "Rudolph"};
12
13    //      type       element        range (e.g. list/vector)
14    //       |           |              |
15    //       ▼           ▼              ▼
16    for (std::string reindeer : reindeers)
17    {
18      std::cout << "Reindeer " << reindeer << std::endl;
19    }
```

element variable

range (list)

Use element

- Reindeer vector is not modified/changed

Example Program Output:

```
./cmake-build/bin/For3
Reindeer Dasher
Reindeer Dancer
Reindeer Prancer
Reindeer Vixen
Reindeer Comet
Reindeer Cupid
Reindeer Donner
Reindeer Blitzen
Reindeer Rudolph
```

Range-based For Loop – Auto!

- C++ 11 introduced the auto keyword
- auto declares a variable whose type is deduced/inferred
- auto n = 10 ; The variable n is of type int
- Range-based for loops can use auto to deduce the type of the *element* inside of the range
- This makes code less verbose

type

src/For3.cpp

```
1  #include <iostream>
2  #include <string>
3  #include <vector>
4
5  int main()
6  {
7    // List of all reindeers
8    std::vector<std::string> reindeers{"Dasher", "Dancer", "Prancer",
9                                       "Vixen", "Comet", "Cupid",
10                                      "Donner", "Blitzen",
11                                      "Rudolph"};
12
13   // type is automatically inferred from 'reindeers' vector
14   for (auto reindeer : reindeers)
15   {
16     std::cout << "Reindeer " << reindeer << std::endl;
17   }
18
19   std::cout << "Finished Loops!\n";
20 }
```

Assignment – Count Digits

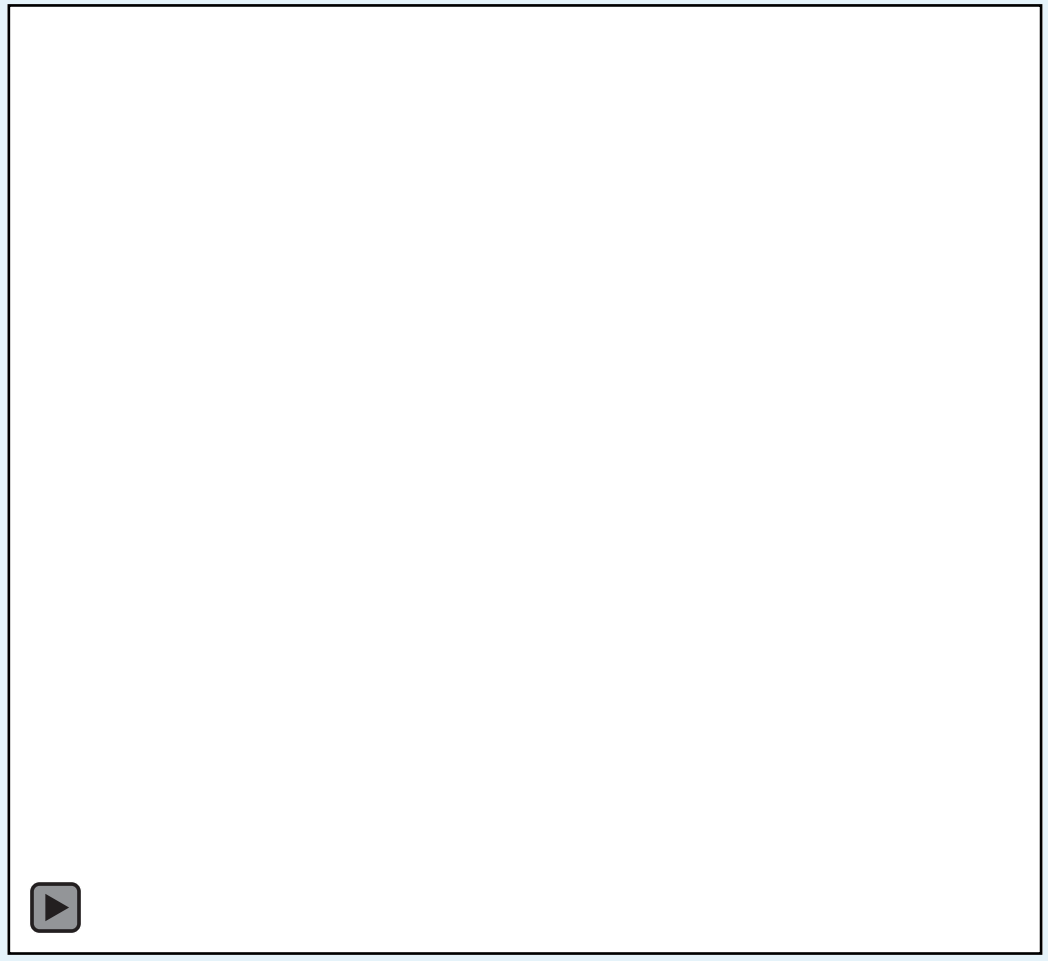
- Create a program that reads an integer and counts the number of digits; display the result
- Solve this problem using loops
- Think about which type of loop would work best in this example
- Hints: The decimal place of a number is moved left by dividing by 10

```
Jeremy@DESKTOP-QD77K4V MSYS ~/Documents/UMICH/jobs/LoopIt/cmake-build (dev)
$ ./bin/Release/CountDigit.exe
Type in your integer: 99
Total Digits: 2
(unreal)
Jeremy@DESKTOP-QD77K4V MSYS ~/Documents/UMICH/jobs/LoopIt/cmake-build (dev)
$ ./bin/Release/CountDigit.exe
Type in your integer: 88
Total Digits: 2
(unreal)
Jeremy@DESKTOP-QD77K4V MSYS ~/Documents/UMICH/jobs/LoopIt/cmake-build (dev)
$ ./bin/Release/CountDigit.exe
Type in your integer: 101
Total Digits: 3
(unreal)
```

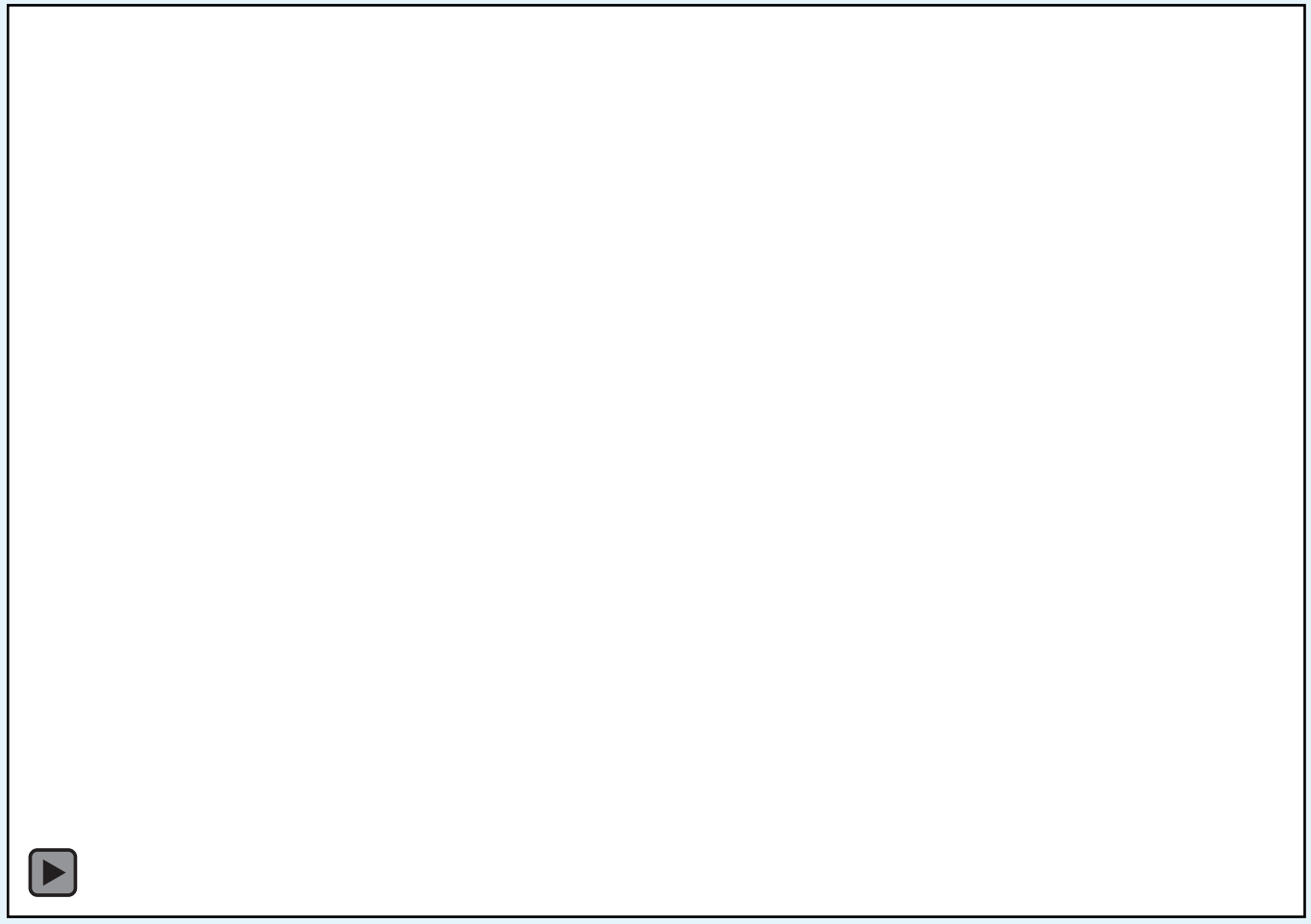
Help! My program won’t stop!

If you ever run into a situation where your program won't terminate with CTRL-C

Windows – Task Manager



Linux – htop



Recap and what's next?

Recap

- Hello World
- Variables
- Conditionals
- **Loops**

What's Next

- Functions!
- Declare them and use in the same file
- Use functions defined across multiple files
  - Learn about C++ linking
- C++11 lambda, AKA anonymous functions