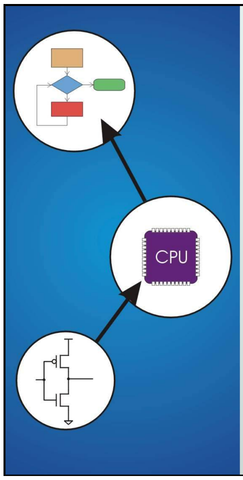


Chapter 11 **Introduction to Programming in C**

Original slides from Gregory Byrd, North Carolina State University

Modified slides by Chris Wilcox, Colorado State University

C: A High-Level Language

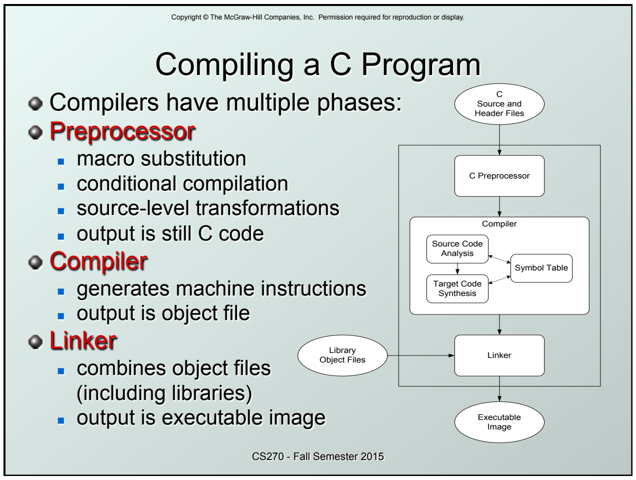
- Gives symbolic names to values
  - don’t need to know register or memory location
- Provides abstraction of underlying hardware
  - operations do not depend on instruction set
  - example: “a = b * c”, even without multiply instruction
- Provides expressiveness
  - use meaningful symbols that convey meaning
  - simple expressions for control patterns (if-then-else)
- Enhances code readability
- Safeguards against bugs
  - enforce rules or conditions at compile-time or run-time

Compilation vs. Interpretation

- Different ways of translating high-level language
- ***Interpretation***
  - interpreter = program that executes program statements
  - generally one line or command at a time
  - limited scope of processing
  - easy to debug, make changes, view intermediate results
  - languages: BASIC, LISP, Perl, Java, Matlab, C-shell
- ***Compilation***
  - Compiler = program that makes an executable from code
  - translates statements into machine language
  - performs optimization over multiple statements
  - change requires recompilation
  - optimized code can be harder to debug
  - languages: C, C++, Fortran, Pascal

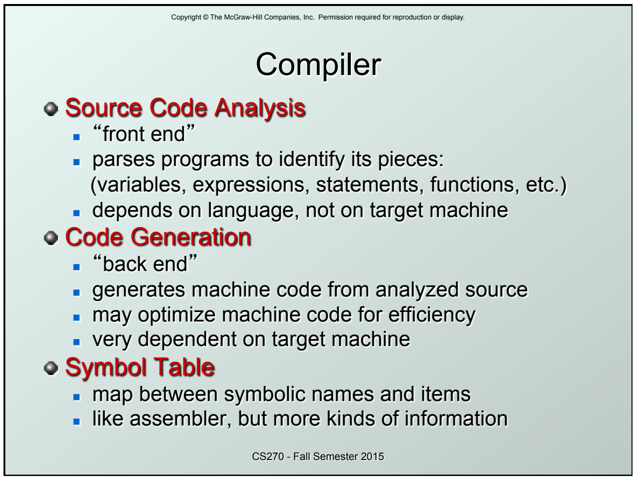
Compilation vs. Interpretation

- Consider the following algorithm:
  - **`Get W from the keyboard.`**
  - **`X = W + W`**
  - **`Y = X + X`**
  - **`Z = Y + Y`**
  - **`Print Z to screen.`**
- If interpreting, how many arithmetic operations?
- If compiling, can we simplify the computation?
- Yes, by analyzing the entire program, we can reduce to single arithmetic operation!



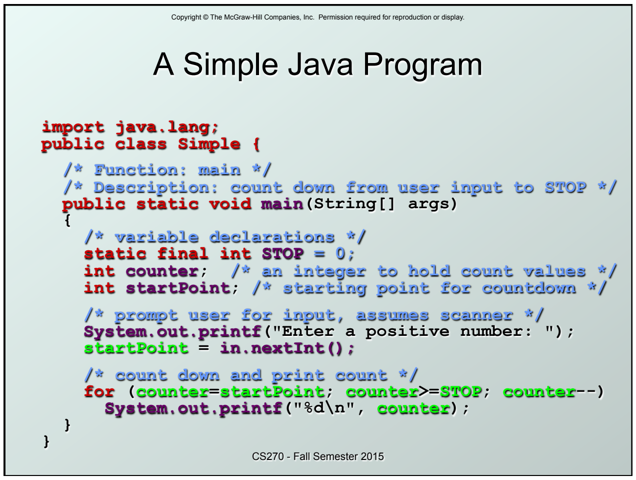
Compiling a C Program

- Compilers have multiple phases:
- Preprocessor
  - macro substitution
  - conditional compilation
  - source-level transformations
  - output is still C code
- Compiler
  - generates machine instructions
  - output is object file
- Linker
  - combines object files (including libraries)
  - output is executable image



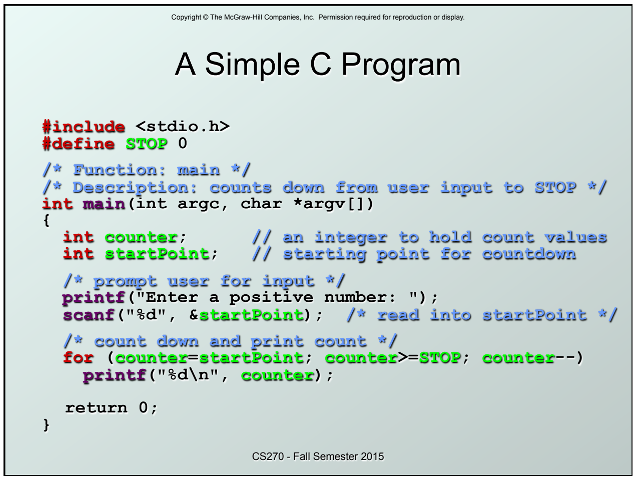
Compiler

- Source Code Analysis
  - “front end”
  - parses programs to identify its pieces: (variables, expressions, statements, functions, etc.)
  - depends on language, not on target machine
- Code Generation
  - “back end”
  - generates machine code from analyzed source
  - may optimize machine code for efficiency
  - very dependent on target machine
- Symbol Table
  - map between symbolic names and items
  - like assembler, but more kinds of information



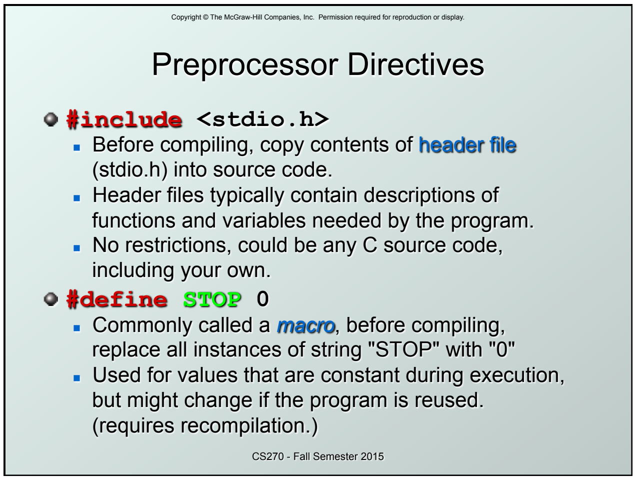
A Simple Java Program

```
import java.lang;
public class Simple {
  /* Function: main */
  /* Description: count down from user input to STOP */
  public static void main(String[] args)
  {
    /* variable declarations */
    static final int STOP = 0;
    int counter;  /* an integer to hold count values */
    int startPoint; /* starting point for countdown */

    /* prompt user for input, assumes scanner */
    System.out.printf("Enter a positive number: ");
    startPoint = in.nextInt();

    /* count down and print count */
    for (counter=startPoint; counter>=STOP; counter--)
      System.out.printf("%d\n", counter);
  }
}
```



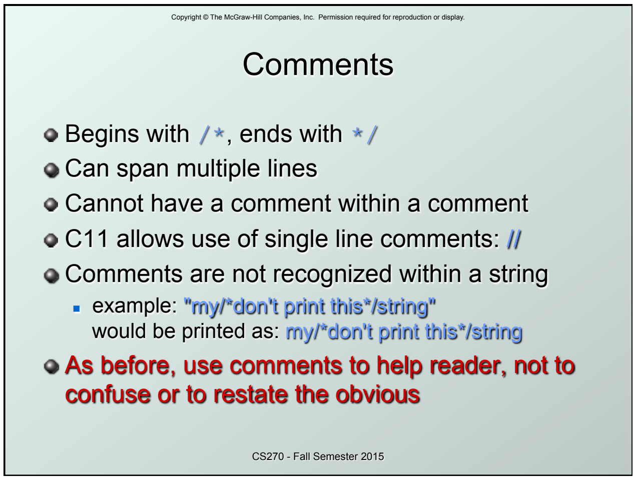
A Simple C Program

```
#include <stdio.h>
#define STOP 0

/* Function: main */
/* Description: counts down from user input to STOP */
int main(int argc, char *argv[])
{
  int counter;      // an integer to hold count values
  int startPoint;   // starting point for countdown

  /* prompt user for input */
  printf("Enter a positive number: ");
  scanf("%d", &startPoint);  /* read into startPoint */

  /* count down and print count */
  for (counter=startPoint; counter>=STOP; counter--)
    printf("%d\n", counter);

  return 0;
}
```



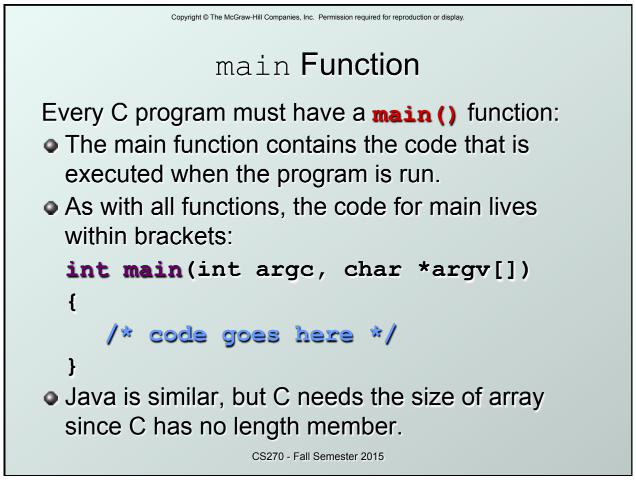
Preprocessor Directives

- `#include <stdio.h>`
  - Before compiling, copy contents of header file (stdio.h) into source code.
  - Header files typically contain descriptions of functions and variables needed by the program.
  - No restrictions, could be any C source code, including your own.
- `#define STOP 0`
  - Commonly called a *macro*, before compiling, replace all instances of string "STOP" with "0"
  - Used for values that are constant during execution, but might change if the program is reused. (requires recompilation.)



Comments

- Begins with `/*`, ends with `*/`
- Can span multiple lines
- Cannot have a comment within a comment
- C11 allows use of single line comments: //
- Comments are not recognized within a string
  - example: "my/*don't print this*/string"
    would be printed as: my/*don't print this*/string
- **As before, use comments to help reader, not to confuse or to restate the obvious**



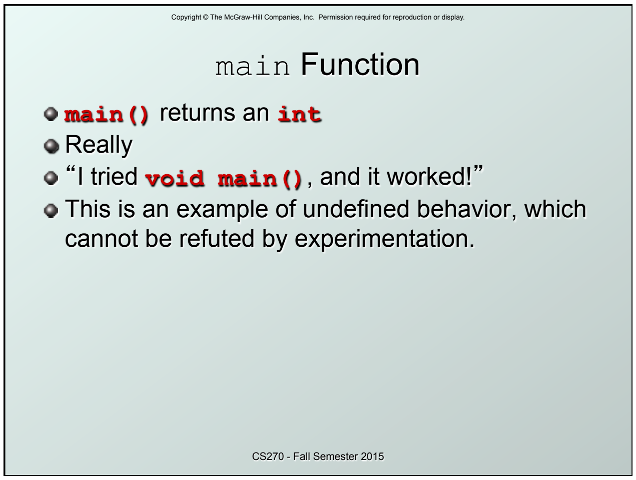
`main` Function

Every C program must have a `main()` function:

- The main function contains the code that is executed when the program is run.
- As with all functions, the code for main lives within brackets:

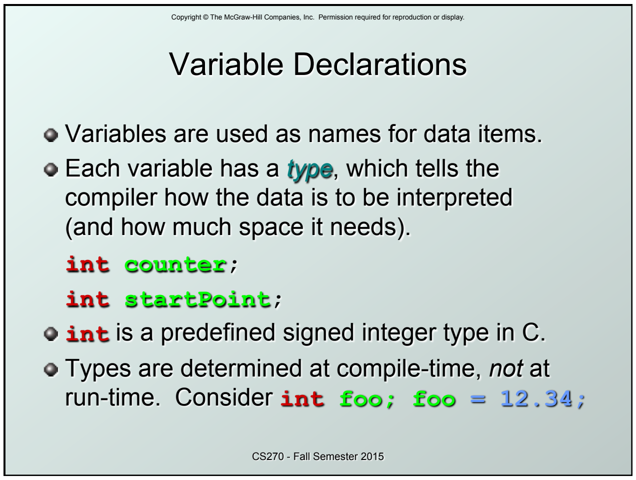
```
int main(int argc, char *argv[])
{
   /* code goes here */
}
```

- Java is similar, but C needs the size of array since C has no length member.



`main` Function

- `main()` returns an `int`
- Really
- “I tried `void main()`, and it worked!”
- This is an example of undefined behavior, which cannot be refuted by experimentation.

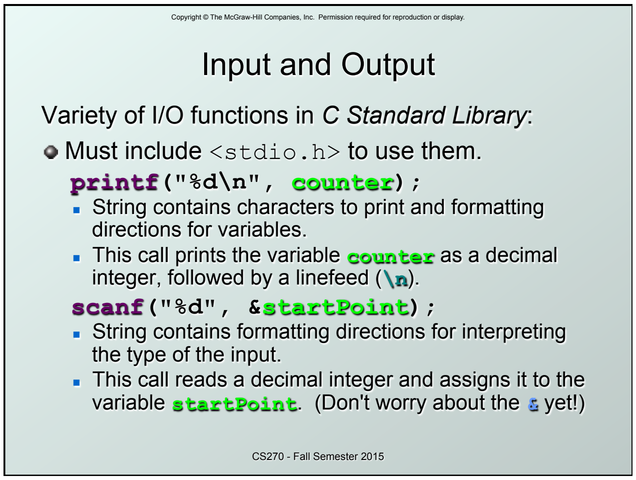


Variable Declarations

- Variables are used as names for data items.
- Each variable has a *type*, which tells the compiler how the data is to be interpreted (and how much space it needs).

```
int counter;
int startPoint;
```

- `int` is a predefined signed integer type in C.
- Types are determined at compile-time, *not* at run-time. Consider `int foo; foo = 12.34;`



Input and Output

Variety of I/O functions in *C Standard Library*:

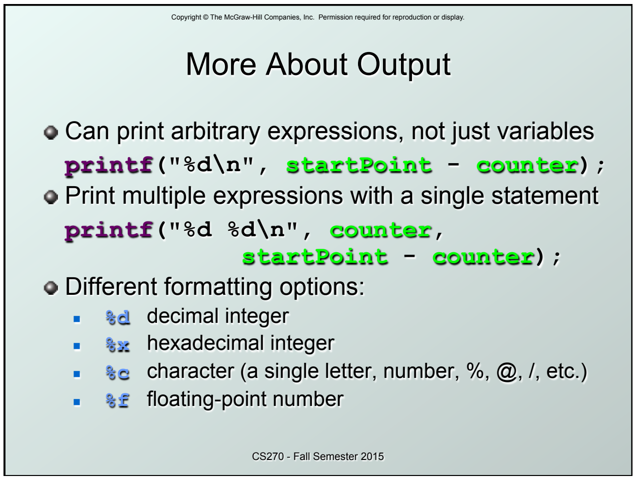
- Must include `<stdio.h>` to use them.

```
printf("%d\n", counter);
```

  - String contains characters to print and formatting directions for variables.
  - This call prints the variable `counter` as a decimal integer, followed by a linefeed (`\n`).

```
scanf("%d", &startPoint);
```

  - String contains formatting directions for interpreting the type of the input.
  - This call reads a decimal integer and assigns it to the variable `startPoint`. (Don't worry about the `&` yet!)



More About Output

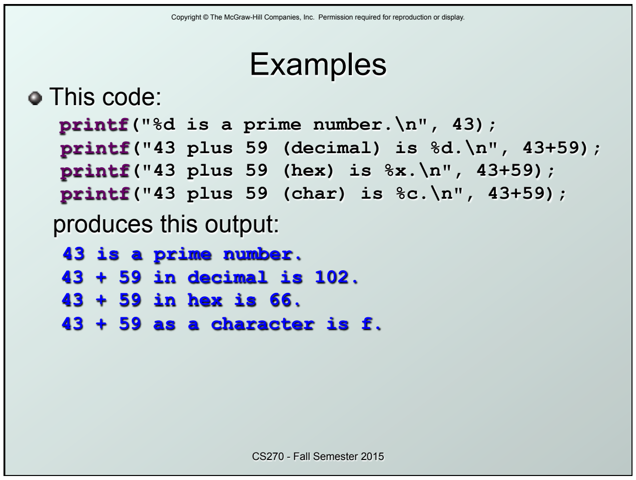
- Can print arbitrary expressions, not just variables

```
printf("%d\n", startPoint - counter);
```

- Print multiple expressions with a single statement

```
printf("%d %d\n", counter,
              startPoint - counter);
```

- Different formatting options:
  - `%d` decimal integer
  - `%x` hexadecimal integer
  - `%c` character (a single letter, number, %, @, /, etc.)
  - `%f` floating-point number



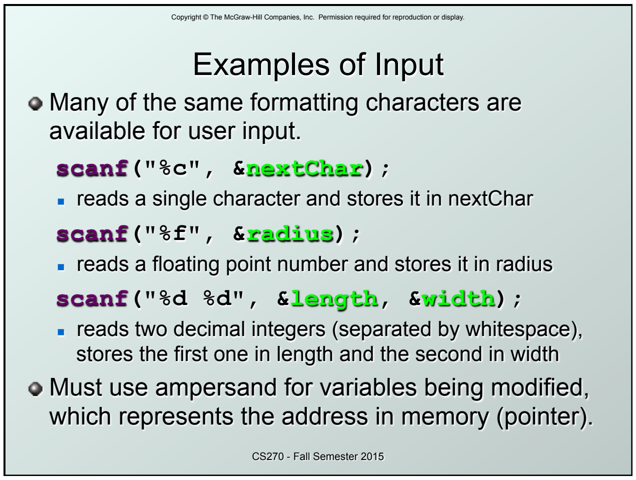
Examples

- This code:

```
printf("%d is a prime number.\n", 43);
printf("43 plus 59 (decimal) is %d.\n", 43+59);
printf("43 plus 59 (hex) is %x.\n", 43+59);
printf("43 plus 59 (char) is %c.\n", 43+59);
```

produces this output:

```
43 is a prime number.
43 + 59 in decimal is 102.
43 + 59 in hex is 66.
43 + 59 as a character is f.
```



Examples of Input

- Many of the same formatting characters are available for user input.

```
scanf("%c", &nextChar);
```

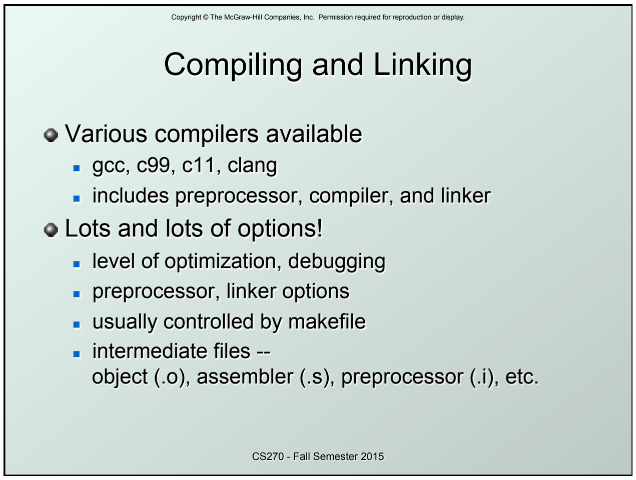
  - reads a single character and stores it in nextChar

```
scanf("%f", &radius);
```

  - reads a floating point number and stores it in radius

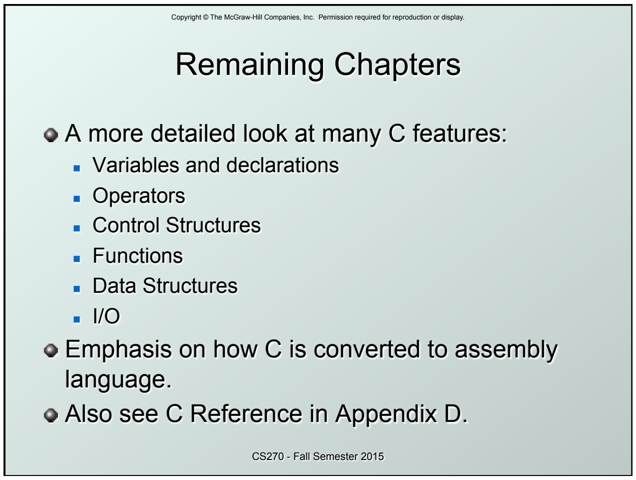
```
scanf("%d %d", &length, &width);
```

  - reads two decimal integers (separated by whitespace), stores the first one in length and the second in width
- Must use ampersand for variables being modified, which represents the address in memory (pointer).



Compiling and Linking

- Various compilers available
  - gcc, c99, c11, clang
  - includes preprocessor, compiler, and linker
- Lots and lots of options!
  - level of optimization, debugging
  - preprocessor, linker options
  - usually controlled by makefile
  - intermediate files --
    object (.o), assembler (.s), preprocessor (.i), etc.



Remaining Chapters

- A more detailed look at many C features:
  - Variables and declarations
  - Operators
  - Control Structures
  - Functions
  - Data Structures
  - I/O
- Emphasis on how C is converted to assembly language.
- Also see C Reference in Appendix D.