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C: History & Context

What is C?

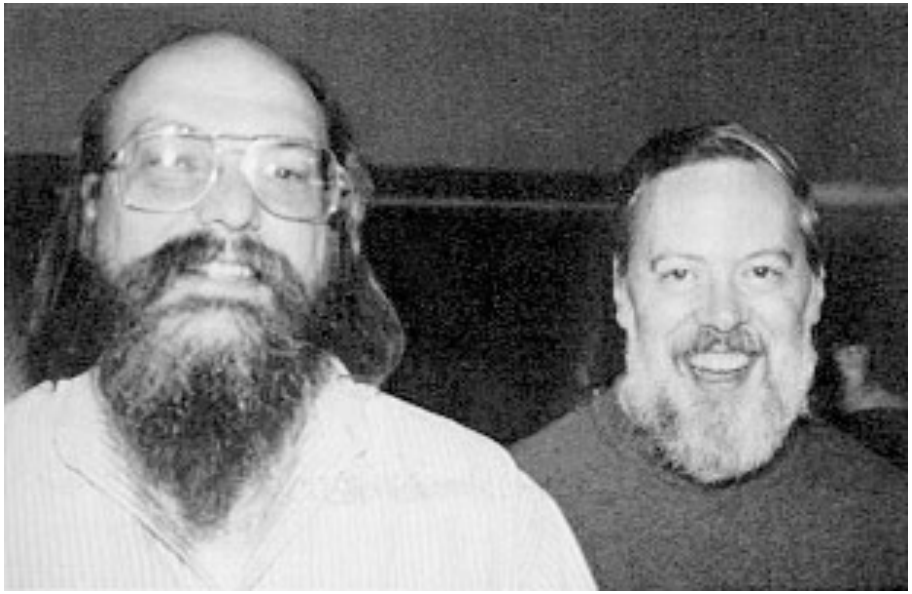
- C is a general-purpose, procedural, imperative programming language.
- C provides constructs that map efficiently to typical *machine instructions*, and therefore it has found lasting use in applications that had formerly been coded in *assembly language*.
- "C combines the power and performance of assembly with the flexibility and ease-of-use of assembly."
- C is one of the most widely used programming languages *of all time*.

History of C & Unix

- The origin of C is closely tied to the development of the Unix operating system.
- Unix was developed by Ken Thompson and Dennis Ritchie as the operating system for a system called the PDP-7.
- C was developed by Dennis Ritchie between 1969 and 1973 at AT&T Bell Labs, and used to *re-implement* the Unix operating system for a system called a PDP-11.
- Prior to the development of Unix, most operating system programming was done in *system-dependent assembly language*. No portability of operating systems as a result!

History of the world

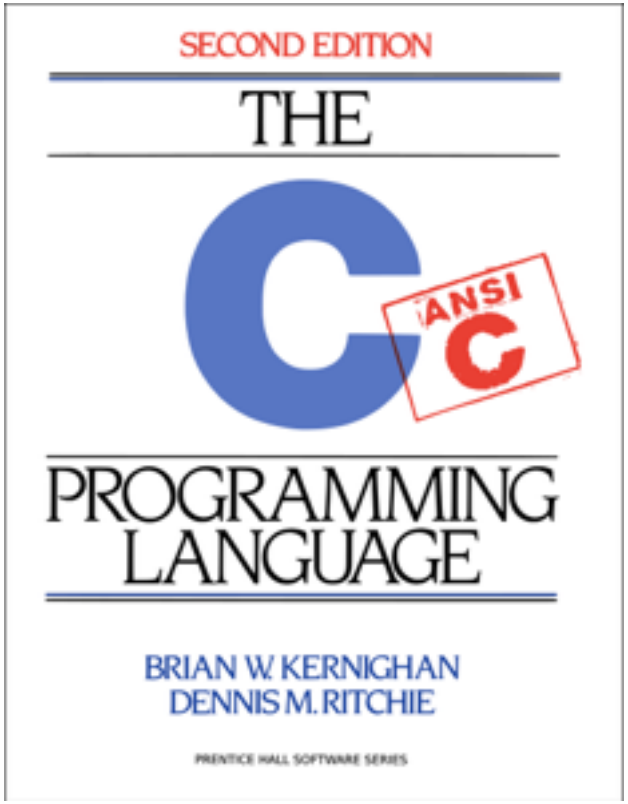
- Pretty much everything on the web uses those two things: C and Unix.
- Windows was once written in C,
- Unix underpins both Mac OS X and iOS.
- Linux is a derivative of Unix and powers the majority of the worlds servers.
- The list goes on and on and on…
- Denis Ritchie passed in 2011
  http://www.wired.com/2011/10/thedennisritchieeffect/



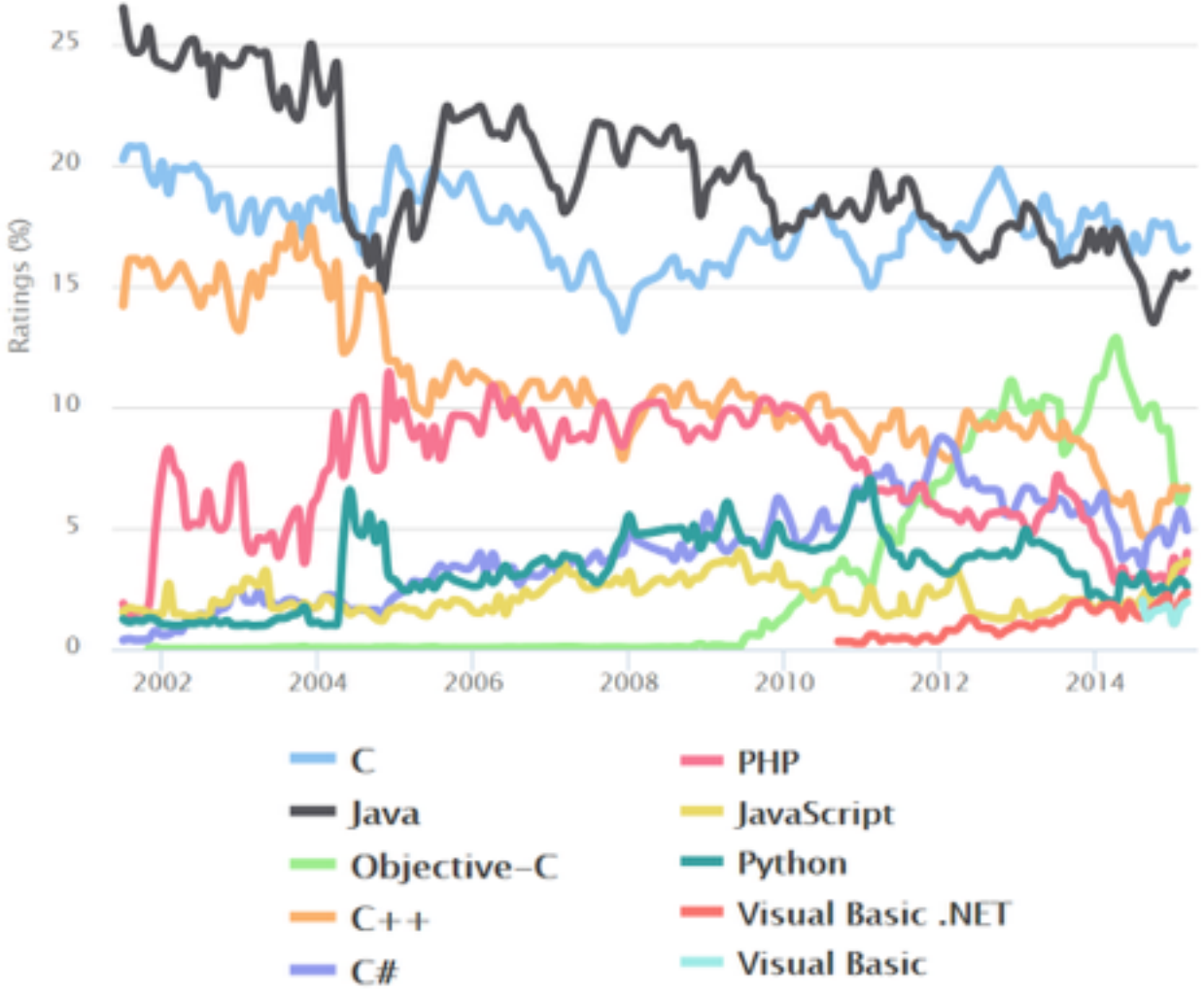
left: Ken Thompson, right: Denis Ritchie

Yet another contribution

- In 1978, Brian Kernighan and Dennis Ritchie published the first edition of The C Programming Language
- This book, known to C programmers as “K&R"
- The second edition of the book covers the later ANSI C standard.



Is C still in wide use?



Modern C use cases

- C is widely used for "system programming", including implementing operating systems and embedded system applications.
- Other programming languages are often implemented in C. The implementations of Python, Perl 5 and PHP are all written in C.
- C allows efficient implementations of algorithms and data structures, which is useful for programs that perform a lot of computation.
- Excellent for learning! As you are "*close to the metal*".
- Development of end-user applications has shifted to newer, higher-level languages, such as Java.

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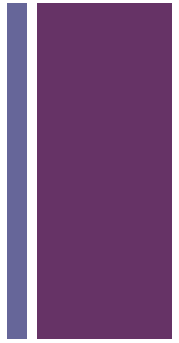
C vs Java

Comparison to Java

Thing	C	Java
type of language	procedural	object-oriented
basic program unit	function	class
portability of source code	maybe	yes
portability of compiled code	no	yes
compilation	creates machine language code	creates JVM 'bytecode'
execution	OS loads and executes program	JVM loads byte code and interprets the program
memory management	manual	automatic

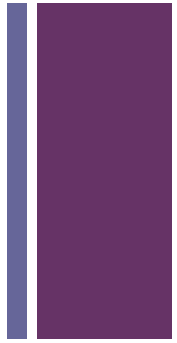
more here http://introcs.cs.princeton.edu/java/faq/c2java.html

Comparison to Java: data types



- C has many of the same data types as Java
  - integer types: short, int, long
  - floating point types: float, double
- There are significant differences here in the type systems.
- While both Java and C are “statically typed”, Java is said to be “strongly & statical typed” whereas C is often said to be “weakly & statically typed”

Comparison to Java: operators

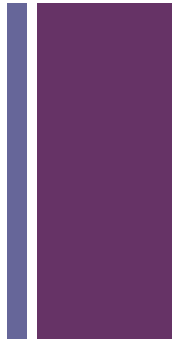


- C has the same set of mathematical operators as Java.
- Precedence and associatively rules related to operators are also the same.

Comparison to Java: control flow

- C has some of the same syntax same as Java…
  - if ( ) { } else { }
  - while ( ) { }
  - do { } while ( );
  - for(i=1; i <= 100; i++) { }
  - etc…
- Syntactically there is a fair amount of knowledge you can transfer

Comparison to Java: in general



- There are a number of similarities, but many more differences.
- It may look familiar to you, since C influenced a great number of languages.
- Syntax we take for granted as just “programming” are often descended from C.
- Don’t that that lull you into a false sense of security.

‘Hello World’ in Java & C

```
public class HelloWorld {
   /* A simple Java program */
   public static void main(String[] args)
   {
      System.out.println("Hello World!");
   }
}
```

```
#include <stdio.h>
/* A simple C program */
int main()
{
  printf(“Hello World\n”);
  return 0;
}
```

‘Hello World’ in C in detail

#include inserts another file. “.h” files are called “header” files. They contain stuff needed to interface to libraries and code in other “.c” files.

This is a comment. The compiler ignores this.

```
#include <stdio.h>
/* A simple C program */
int main()
{
  printf(“Hello World\n”);
  return 0;
}
```

The main() function is always where your program starts running.

Blocks of code (“lexical scopes”) are marked by { … }

Return ‘0’ from this function

Print out a message. ‘\n’ means “new line”.

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C's Compile and Execute Cycle

Writing and running C

- Write text of program using an editor such as sublime, save as file e.g. my_program.c
- From command line, run the compiler to convert program from source to an “executable” or “binary”…

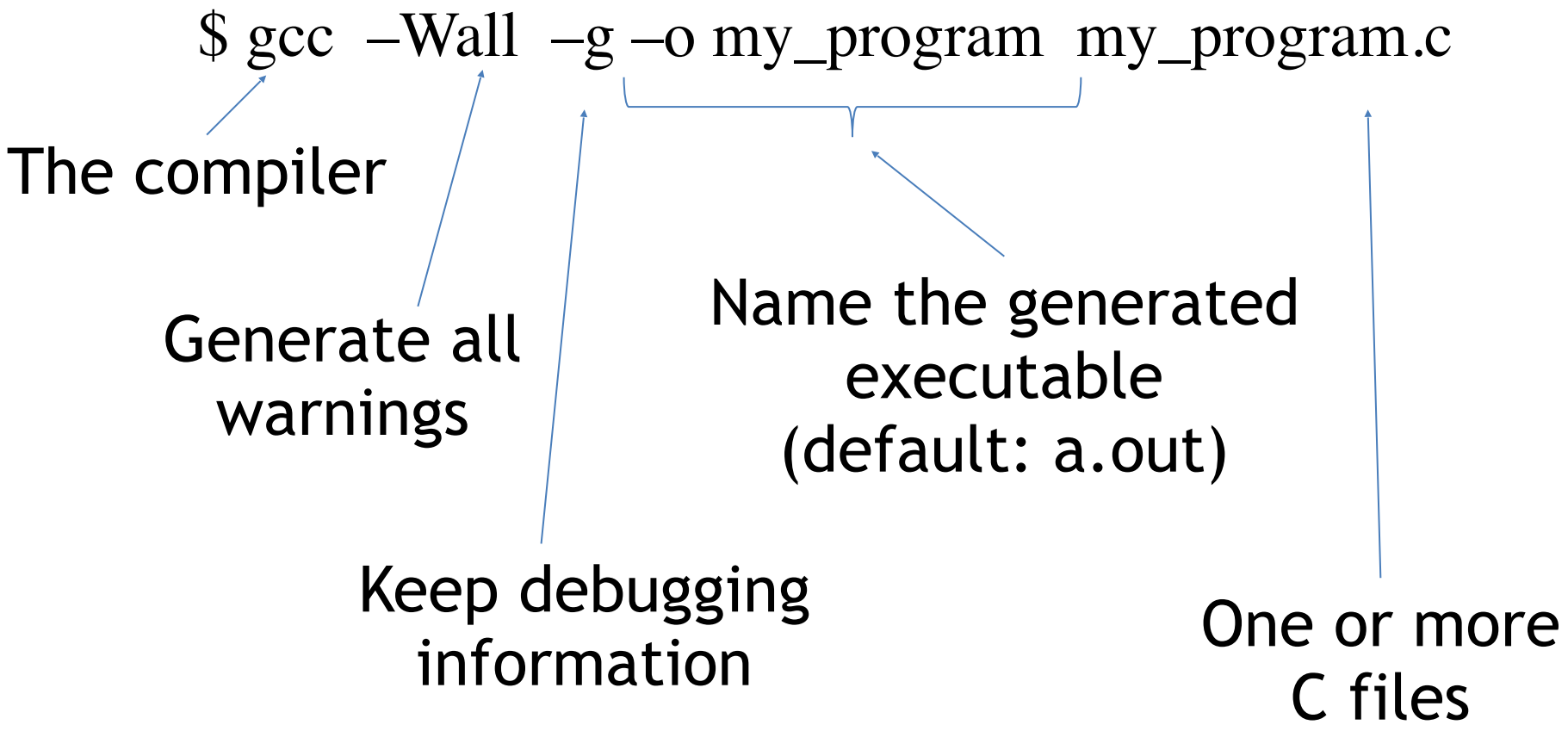
  gcc -Wall -g -o my_program my_program.c

- (Compiler may give errors or warnings; edit source file, fix and re-compile)
- From the command line, execute program like so…

  ./my_program

- If runtime errors occur, debug, re-compile and execute.

Compilation command in detail

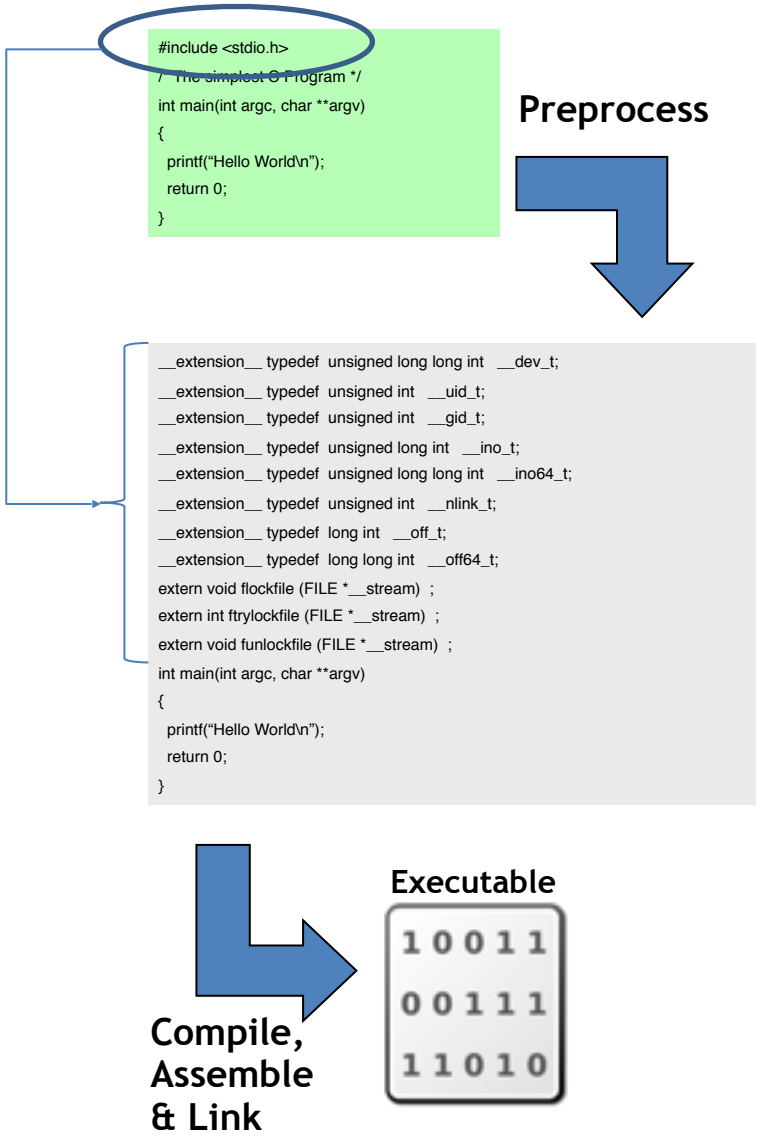


What really happens when we compile?

- When you type **gcc** you really initiate four different ‘stages’ that execute in sequence.
  - Preprocessing
  - Compilation
  - Assembly
  - Linking

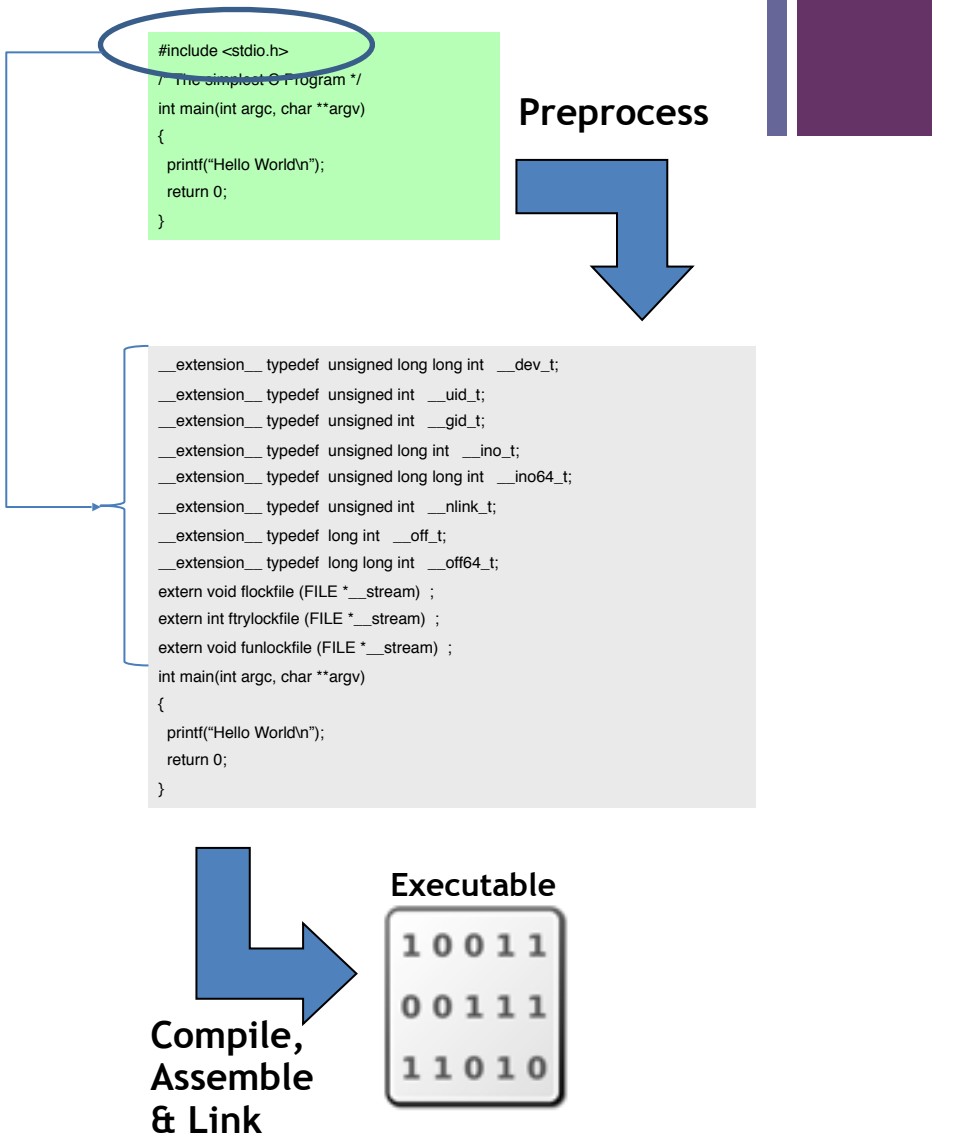
Preprocessing

- Source code is “expanded” into a larger form that is simpler for the compiler to work with.
- Any line that starts with ‘#’ is a line that is interpreted by the ‘preprocessor’.
- Include files are “pasted in” (#include)
- Comments are stripped out (/* */ , //)
- Continued lines (i.e. very long lines) are joined (\ )
- Other things like ‘macro expansion’



Compiling, Assembling & Linking

- The compiler converts the resulting text into binary code the CPU can run directly.
- The compilation process involves really several steps:
  - *Compiler*: C → Assembly
  - *Assembler*: Assembly → Object Code
  - *Linker*: Links object code and needed libraries into one executable file.



Viewing intermediate states of compilation

- We can run only pre-processing by giving the **-E** option to gcc.
  - ex. **gcc -E my_program.c > my_program.i**
- We can view the assembly generated by giving the **-S** option to gcc
  - ex. **gcc -S my_program.c**
  - By default this will output to a file called my_program.s
- We can stop only generate the object code by giving the **-c** option to gcc
  - ex. **gcc -c hello.c**

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C Data Types

Data Types

- This table lists the data types in C together with their min size (in bytes) on a 32-bit and 64-bit systems.

type	size (32bit)	size (64bit)	example
`char`	1	1	`char c = 'a';`
`short`	2	2	`short s = 175;`
`int`	4	4	`int i = 2147483647;`
long	4	8	long int l = 2147483647;
long long	8	8	long long int ll = 9223372036854775807;
float	4	4	float f = 1.0;
double	8	8	double d = 1.0;
pointer	4	8	int *x = NULL;

- There is also the concept of 'signed' and 'unsigned' integer types.
  - Using the keyword 'unsigned' changes the range of representation.

Data Types: Boolean

- Note that there was no ‘boolean’ type.
- C integer types represent true/false.
  - Zero is always interpreted as false
  - *Any other value* is interpreted as true.
- ex.

```
int i = 0;
if (i) {
  printf(“false");
else
  printf("true");
```

type	size (32bit)	size (64bit)
`char`	1	1
`short`	2	2
`int`	4	4
long	4	8
long long	8	8
float	4	4
double	8	8
pointer	4	8

Data Types: Char

- C's 'char' is different than Java's char type.
- It is more similar to Java's byte type, lets see if you can spot why.
- K&R defines a char as follows:
  - "a single byte, capable of holding one character in the local character set."
- Whats the problem here?

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  - Modern character encodings require more bytes!!

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Data Types: Pointers

- Java has no such data type as a pointer.
  - At least not explicitly.
- Java "Reference Types" in many ways behave similarly to pointers.
- When we learn about pointers in details I will argue that, if you understand Java "Reference Types" you in fact, already know a fair amount about pointers.

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Printing Data Types

- The printf function provides way of printing values of variables of different data types.
- We need to know the format specifier that printf expects for each given type.
- See types/types.c

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C Basics

Selection statements

- The syntax of the if, if ... else ... and switch statements are very similar to Java.
- The expression in the switch statement has to have an *integral* value (int, char, or an expression that evaluates to an integral value).
- See conditionals/conditionals.c

```
char lcase = 'b'
char ucase;
switch (lcase) {
   case 'a' :
      ucase = 'A';
      break;
   case 'b' :
      ucase = 'B';
      break;
   default:
      break;
}
printf("ucase: %c\n", ucase);
```

Looping

- C also has three different loops: for loop, while loop, and do/while
- Note that the control variable has to be declared before the loop!
- You can use ‘break’ & ‘continue’ just as in Java.
- See loops/loops.c

```
int i;
for (i = 0; i < 10; i++) {
   print("i=%d\n",i);
}
```

```
int i = 10;
while (i > 0) {
   print("i=%d\n",i);
   i--;
}
```

```
int i = 10;
do {
   print("i=%d\n",i);
   i--;
} while (i > 0)
```

GOTO

- Don’t even think about it.
- I am not even going to explain it.
- They are generally considered to be bad programming style and result in code that is hard to understand and debug

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Reference

GCC argument summary

- GCC is the compiler, some of its options are…
  - –Wall : generate all warnings
  - –g : keep debugging information in another file
  - –o : followed by non-default name of executable
  - -E : only run preprocessor
  - -S : output only assembly
  - -c : output only object code
- Other options can be discovered by typing ‘man gcc’