MORE FUNCTIONS
MAKEFILES

Problem Solving with Computers-I

Approximate Equality

What is the correct way to test for approximate equality?

(a) |x - y| < 0.001

(b) |y - x| <= 0.001

(c) |x + y| < |x + y| + 0.001

(d) A and B

(e) A, B, and C

Writing code that works

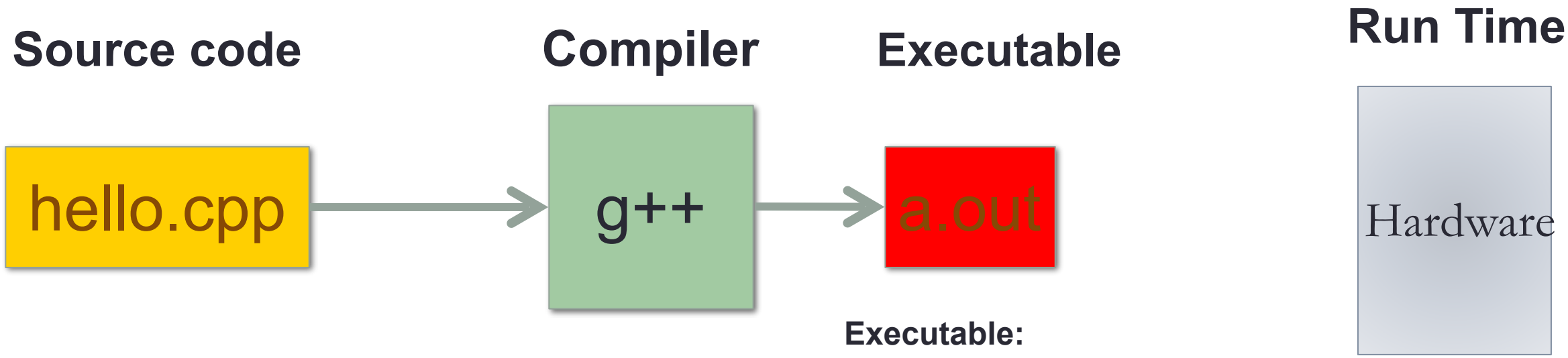
Write a function that RETURNS a string representing

an isosceles triangle with a given width

```
s = drawTriangle(5);
cout<<s;
```

```
  *
 ***
*****
```

The compilation process



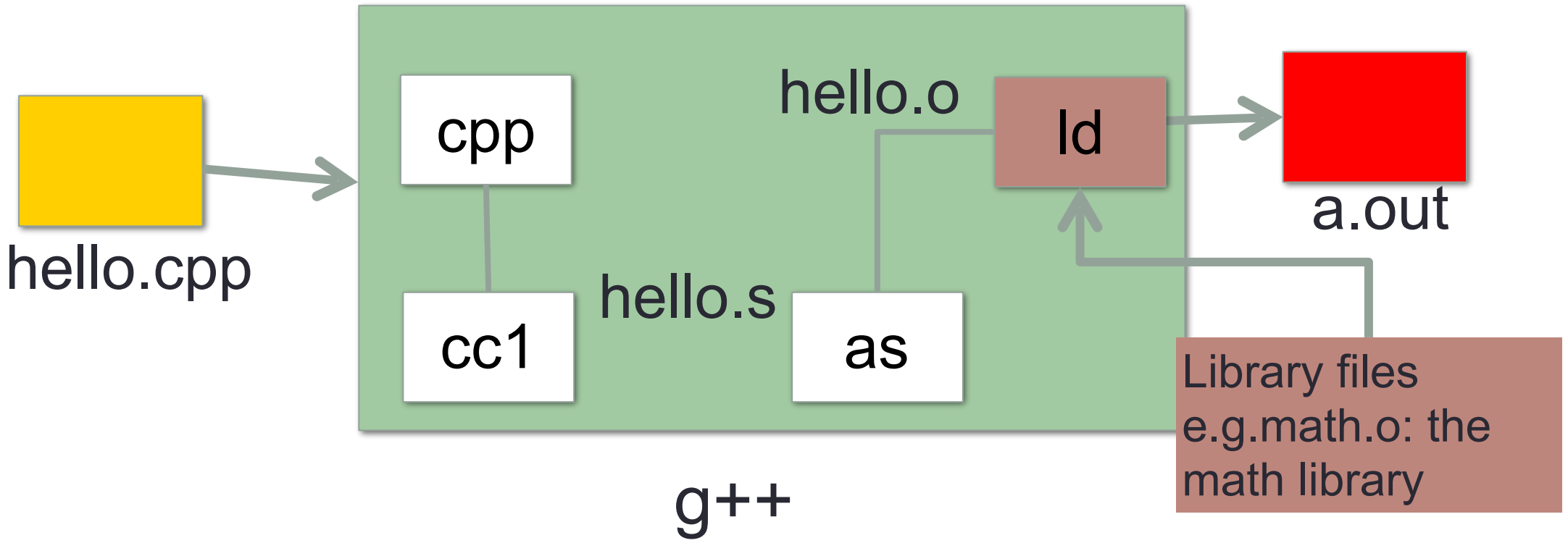
Executable:
Program in machine code
+Data in binary

Source code:
Text file stored on computers hard disk or some secondary storage

```
10001100011000100000000000000000
10001100111100100000000000000100
10101100111100100000000000000000
10101100011000100000000000000100
```

g++ is composed of a number of smaller programs

- Code written by others (libraries) can be included
- ld (linkage editor) merges one or more object files with the relevant libraries to produce a single executable



Steps in gcc

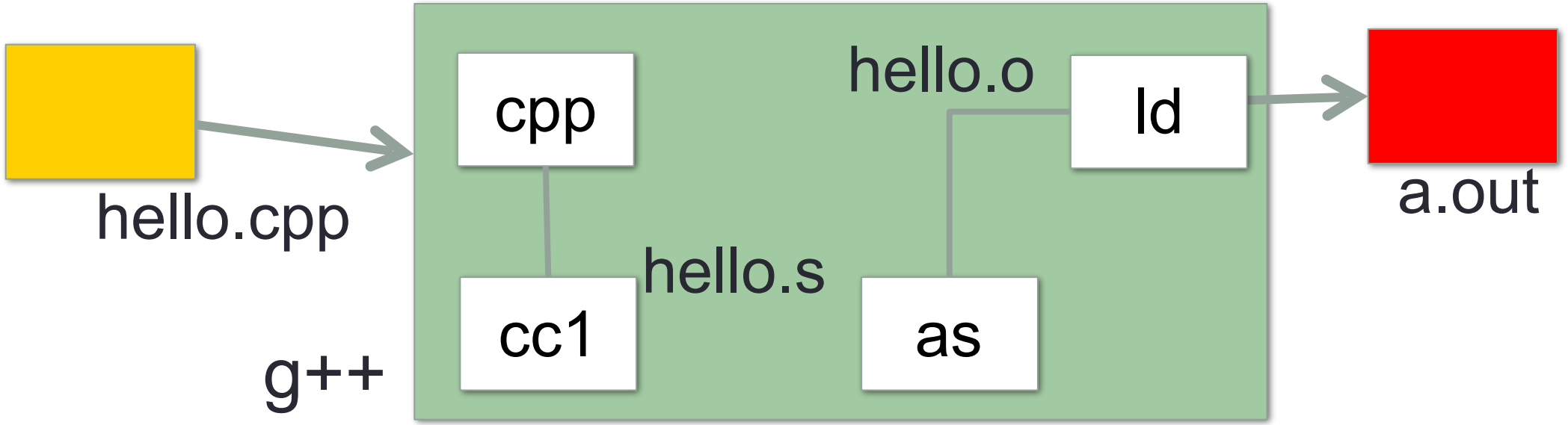
- Ask compiler to show temporary files:

$ g++ –S hello.cpp

$ g++ –c hello.o

$ g++ –o hello hello.cpp

$ g++ functions.o main.o –o myhello



Make and makefiles

- The unix make program automates the compilation process as specified in a Makefile
- Specifies how the different pieces of a program in different files fit together to make a complete program
- In the makefile you provide a recipe for compilation
- When you run make it will use that recipe to compile the program

```
$ make
g++ testShapes.o shapes.o tdd.o -o testShapes
```

Demo

- Basics of code compilation in C++ (review)
- Makefiles (used to automate compilation of medium to large projects) consisting of many files
- We will start by using a makefile to compile just a single program
- Extend to the case where your program is split between multiple files
- Understand what each of the following are and how they are used in program compilation
  - Header file (.h)
  - Source file (.cpp)
  - Object file (.o)
  - Executable
  - Makefile
  - Compile-time errors
  - Link-time errors

Specifying a recipe in the makefile

- **Comments** start with a #
- **Definitions** typically are a variable in all caps followed by an equals sign and a string, such as:

```
CXX=g++
CXXFLAGS=-Wall

BINARIES=proj1
```

```
# testShapes is the target - it is what we want to produce
# To produce the executable testShapes we need all the .o files
# Everything to the right of ":" is a dependency for testShapes

testShapes: testShapes.o shapes.o tdd.o
     #The recipe for producing the target (testshapes) is below
     g++ testShapes.o shapes.o tdd.o -o testShapes
```

NUMBER CONVERSION

Problem Solving with Computers-I

External vs. Internal Representation

- External representation:
  - Convenient for programmer
  - Decimal (base 10)

- Internal representation:
  - Actual representation of data in the computer's memory: Always binary (1's and 0's)

Positional encoding for non-negative numbers

- Each position represents some power of the base

Why is each base important??

Binary representation (base 2)

- On a computer all data is stored in binary
- Only two symbols: 0 and 1
- Each position is called a *bit*
- *Bits take up space*
- 8 bits make a *byte*
- *Example of a 4-bit number*

- Actually the data is voltages
- We use the abstraction:
  - High voltage: 1 (true)
  - Low voltage: 0 (false)

101_5 = ? In decimal

A. 26

B. 51

C. 126

D. 130

Converting between binary and decimal

Binary to decimal: $1\ 0\ 1\ 1\ 0_2 = ?_{10}$

Decimal to binary: $34_{10} = ?_2$

Hex to binary

- Each hex digit corresponds directly to four binary digits
- Programmers love hex, why?

$$25B_{16} = ? \text{ In binary}$$

00	0	0000
01	1	0001
02	2	0010
03	3	0011
04	4	0100
05	5	0101
06	6	0110
07	7	0111
08	8	1000
09	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

Hexadecimal to decimal

$25B_{16}$ = ? Decimal

Hexadecimal to decimal

- Use polynomial expansion
- $25B_{16}$ = 2*256 + 5*16 + 11*1 = 512 + 80 + 11
  = 603
- Decimal to hex: $36_{10}=?_{16}$

Binary to hex: 1000111100

A. 8F0

B. 23C

C. None of the above

BIG IDEA: Bits can represent anything!!

Numbers	Binary Code
0	
1	
2	
3	

How many (minimum) bits are required to represent the numbers 0 to 3?

BIG IDEA: Bits can represent anything!!

Colors	Binary code
Red	
Green	
Blue	

How many (minimum) bits are required to represent the three colors?

BIG IDEA: Bits can represent anything!!

Characters

‘a’
‘b’
‘c’
‘d’
‘e’

N bits can represent at most 2^N things

What is the minimum number of bits required to represent all the letters in the English alphabet in lower case?

A. 3
B. 4
C. 5
D. 6
E. 26

BIG IDEA: Bits can represent anything!!

- Logical values?
  - 0 ⇒ False, 1 ⇒ True
- colors ?

- Characters?
  - 26 letters ⇒ 5 bits ($2^5 = 32$)
  - upper/lower case + punctuation
    ⇒ 7 bits (in 8) (“ASCII”)
  - standard code to cover all the world’s languages ⇒ 8,16,32 bits (“Unicode”)
    www.unicode.com

- locations / addresses? commands?

- MEMORIZE: N bits ⇔ at most 2^N things

What is the maximum positive value that can be stored in a byte?

A. 127

B. 128

C. 255

D. 256

Data types

Binary numbers in memory are stored using a finite, fixed number of bits typically:

8 bits (byte)

16 bits (half word)

32 bits (word)

64 bits (double word or quad)

Data type of a variable determines the:

- exact representation of variable in memory
- number of bits used (fixed and finite)
  - range of values that can be correctly represented