CS 103 Lecture 2 Slides

C/C++ Basics

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Announcements

- Ensure you can gain access to Vocareum.com
- Lab 1 review answers must be submitted on our website
  - Attend lab to meet your TAs and mentors and get help with lab 1

A quick high-level view before we dive into the details…

PROGRAM STRUCTURE AND COMPILATION PROCESS

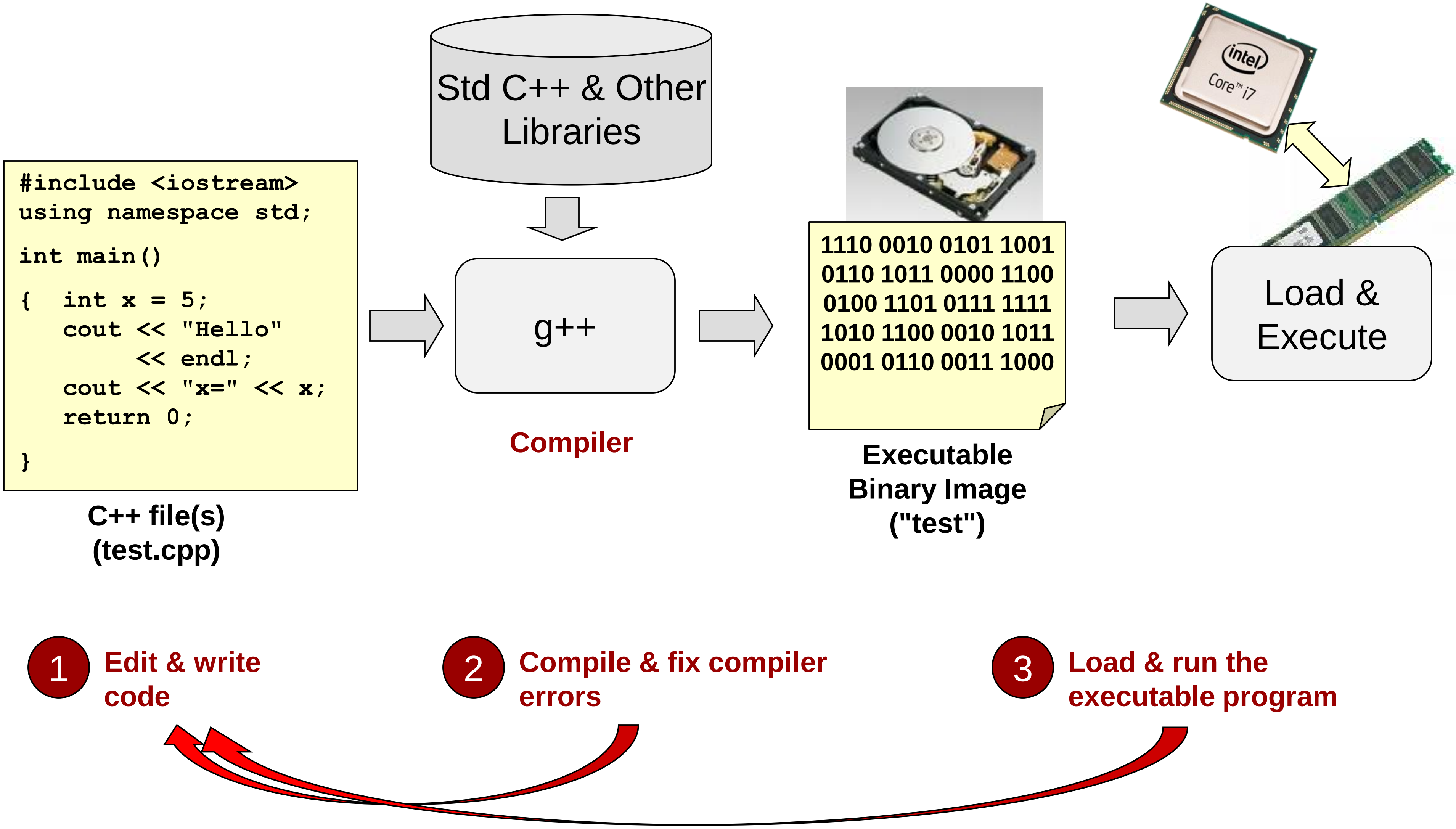
C/C++ Program Format/Structure

- Comments
  - Anywhere in the code
  - C-Style => "/*" and "*/"
  - C++ Style => "//"
- Compiler Directives
  - #includes tell 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 one after the next and end with a semicolon (;)
  - 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;

void printName()
{
  cout << "Tommy Trojan" << endl;
}

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

```
Hello:
Tommy Trojan
Tommy Trojan
```

Software Process



Std C++ & Other Libraries

```
#include <iostream>
using namespace std;

int main()

{  int x = 5;
   cout << "Hello"
        << endl;
   cout << "x=" << x;
   return 0;

}
```

C++ file(s)
(test.cpp)

g++

Compiler

```
1110 0010 0101 1001
0110 1011 0000 1100
0100 1101 0111 1111
1010 1100 0010 1011
0001 0110 0011 1000
```

Executable
Binary Image
("test")

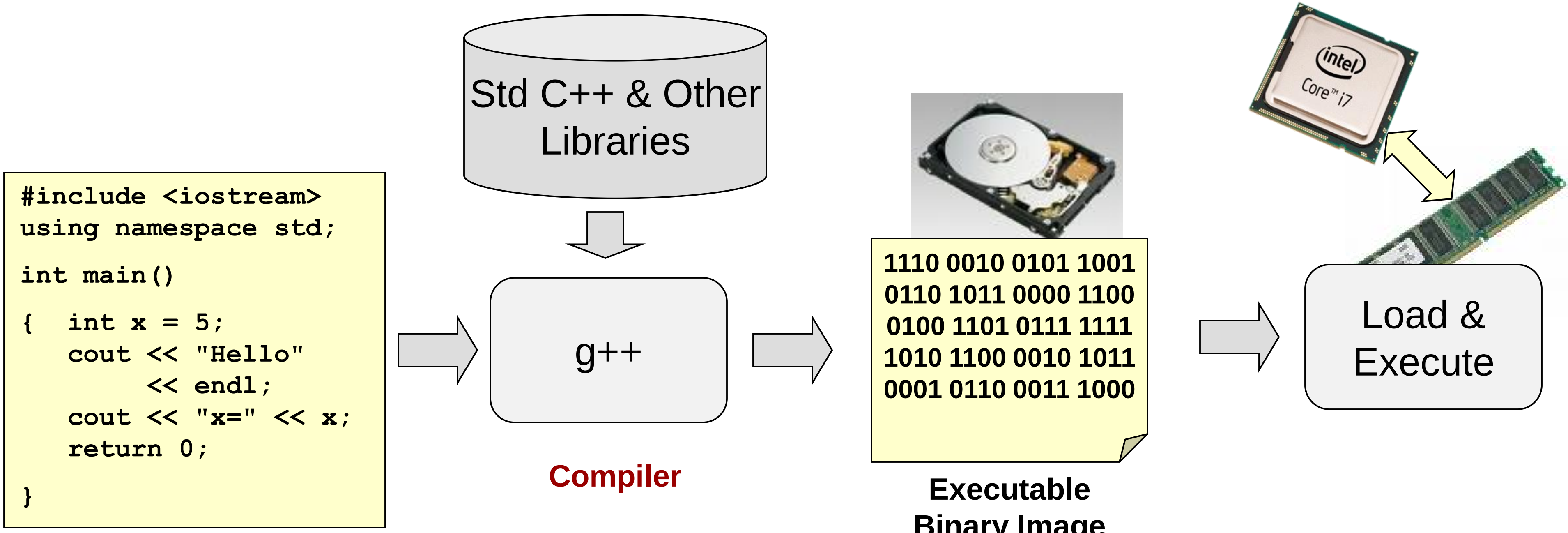
Load &
Execute

1 Edit & write code

2 Compile & fix compiler errors

3 Load & run the executable program

Software Process



```
#include <iostream>
using namespace std;

int main()

{   int x = 5;
    cout << "Hello"
         << endl;
    cout << "x=" << x;
    return 0;

}
```

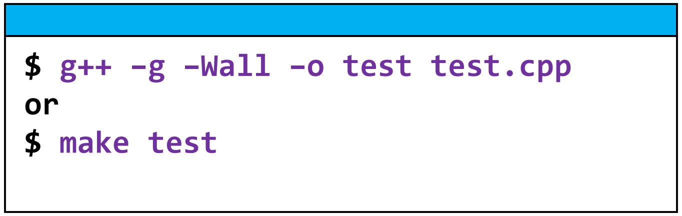
C++ file(s)
(test.cpp)

Compiler

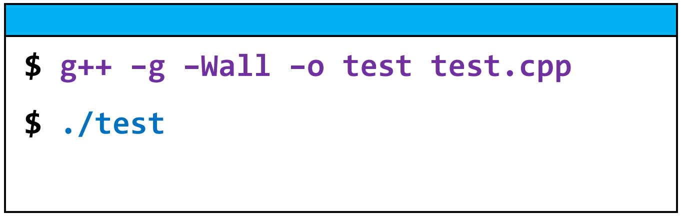
```
1110 0010 0101 1001
0110 1011 0000 1100
0100 1101 0111 1111
1010 1100 0010 1011
0001 0110 0011 1000
```

Executable Binary Image ("test")

-g = Enable Debugging
-Wall =Show all warnings
-o test = Specify Output executable name



```
$ g++ -g -Wall -o test test.cpp
or
$ make test
```



```
$ g++ -g -Wall -o test test.cpp
$ ./test
```

1 Edit & write code

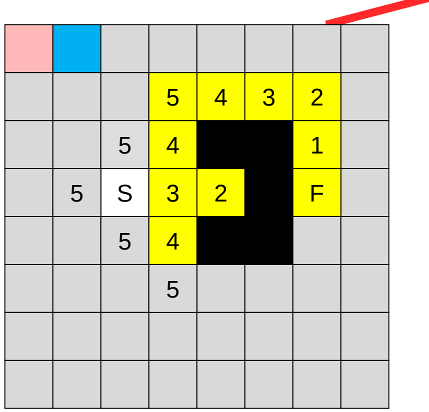
2 Compile & fix compiler errors

3 Load & run the executable program

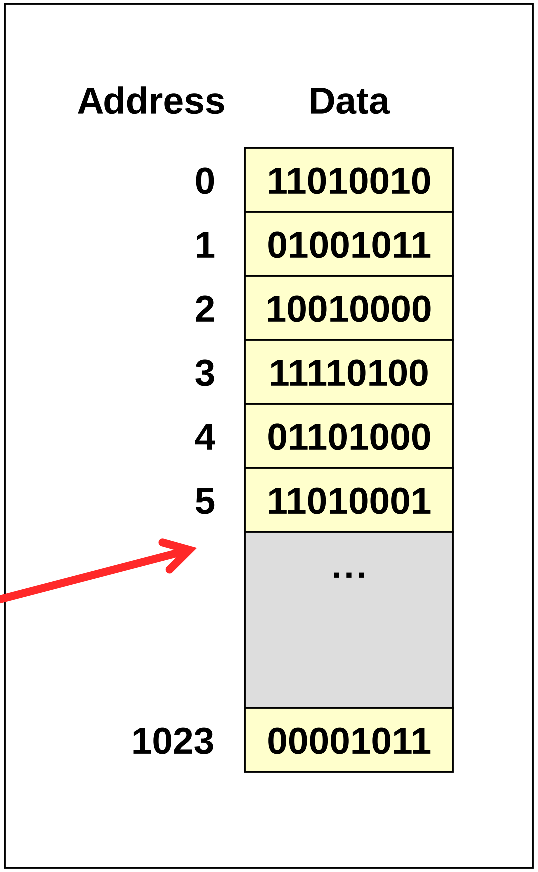
MODULE 1: DATA REPRESENTATION AND TYPES

Memory

- Recall all information in a computer is stored in memory
- Memory consists of cells that each store a group of bits (usually, 1 byte = 8 bits)
- Unique address assigned to each cell
  - Used to reference the value in that location
- We first need to understand the various ways our program can represent data and allocate memory
- When programming it is necessary to understand how data is stored



🟥	🟦						
			5	4	3	2	
		5	4	■	■	1	
	5	S	3	2	■	F	
		5	4	■	■		
			5				



Address	Data
0	11010010
1	01001011
2	10010000
3	11110100
4	01101000
5	11010001
	…
1023	00001011

Memory Device

Starting With Numbers

- A single **bit** can only represent 1 and 0
- To represent more than just 2 values we need to use combinations/sequences of many bits
  - A **byte** is defined as a group 8-bits
  - A **word** varies in size but is usually 32-bits
- So how do we interpret those sequences of bits?
  - Let's learn about number systems

1

A bit

01000001

A byte

0101110 11010001 10110101 01110111

A word

Binary Number System

- Humans use the decimal number system
  - Based on number 10
  - 10 digits: [0-9]
- Because computer hardware uses digital signals with 2 values, computers use the binary number system
  - Based on number 2
  - 2 binary digits (a.k.a bits): [0,1]

Binary Numbers

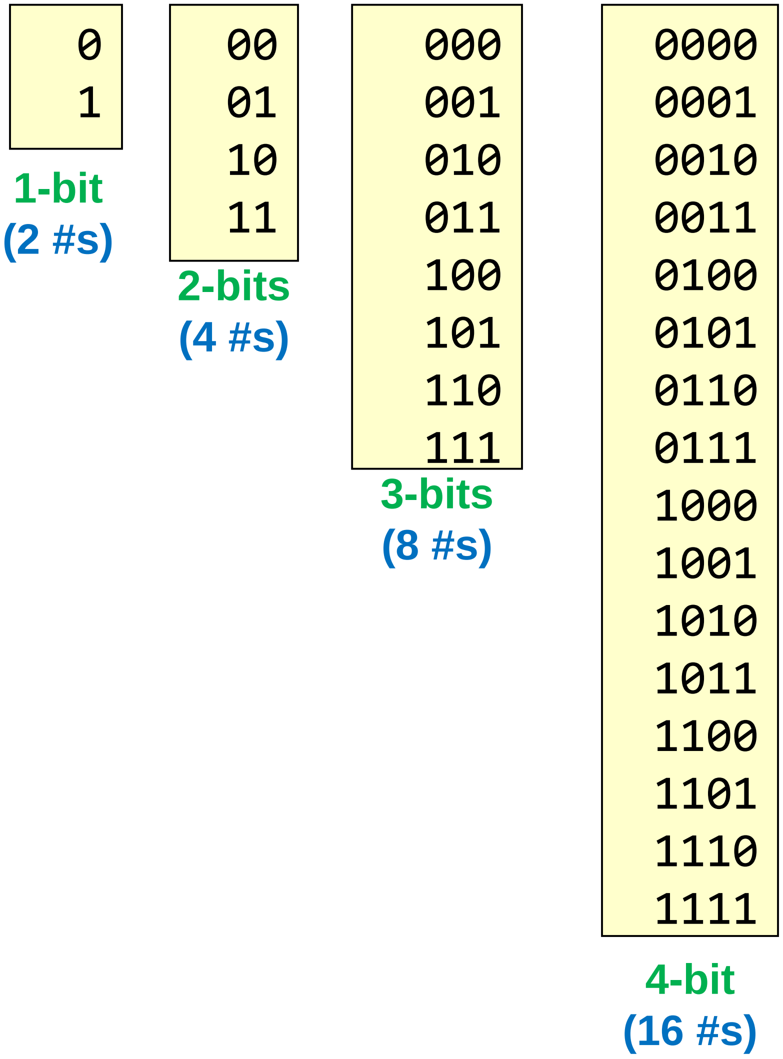
- To represent numbers, there is an implicit **weight** or **place value** for each 1 or 0
- The weights are the powers of 2
  - – $2^0, 2^1, 2^2, 2^3, \ldots$
- The value of the number is the sum of the weights in which there is a 1

0	1	1	0	0	1	1	1	= ______
128	64	32	16	8	4	2	1	

1	0	0	1	1	0	0	1	= ______
128	64	32	16	8	4	2	1	

Combinations

- Because we have a finite number of bits, we can only make a finite set of numbers
- How many numbers (combinations) can we make with n bits?
  - _________
  - Use the examples on the right to induce the relationship of how many #s can be formed with n-bits



0
1

1-bit
(2 #s)

00
01
10
11

2-bits
(4 #s)

000
001
010
011
100
101
110
111

3-bits
(8 #s)

0000
0001
0010
0011
0100
0101
0110
0111
1000
1001
1010
1011
1100
1101
1110
1111

4-bit
(16 #s)

Sign

- Is there any limitation if we only use the powers of some base as our weights?
  - Can't make negative numbers
- What if we change things
  - How do humans represent negative numbers?
  - Can we do something similar?

	512	256	128	64	32	16	8	4	2	1

1024	512	256	128	64	32	16	8	4	2	1

C Integer Data Types

- In C/C++ constants & variables can be of different types and sizes
  - A Type indicates how to interpret the bits and how much memory to allocate
  - Integer Types (signed by default… unsigned with optional leading keyword)

C Type (Signed)	C Type (Unsigned)	Bytes	Bits	Signed Range	Unsigned Range
char	unsigned char	1	8	-128 to +127	0 to 255
short	unsigned short	2	16	-32768 to +32767	0 to 65535
int	unsigned int	4	32	-2 billion to +2 billion	0 to 4 billion
long long	unsigned long long	8	64	$-8*10^{18}$ to $+8*10^{18}$	0 to $16*10^{18}$

C Floating Point Types

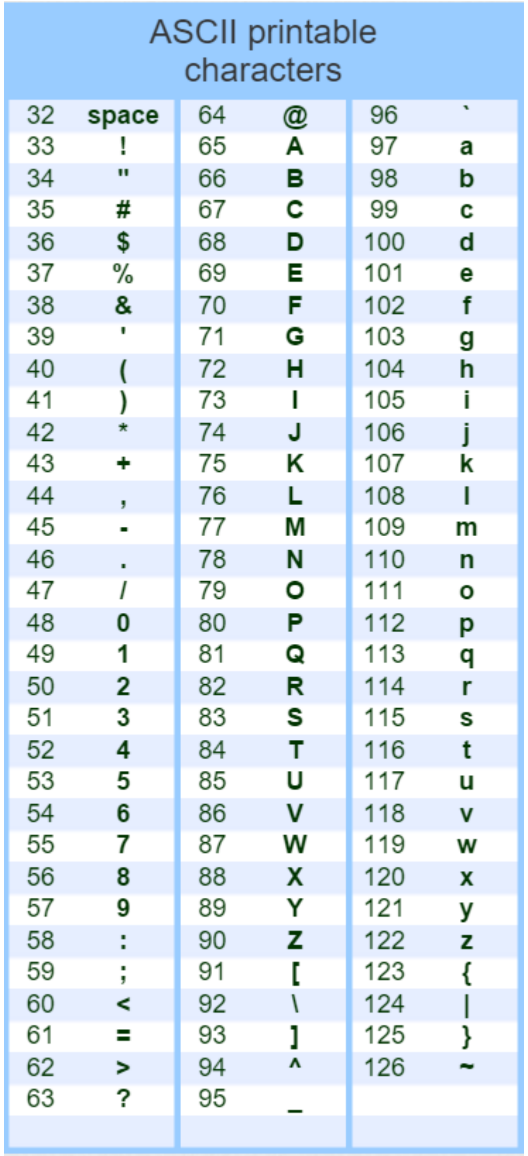
- float and double types:
  - Allow decimal representation (e.g. 6.125) as well as very large integers (+6.023E23)

C Type	Bytes	Bits	Range
float	4	32	±7 significant digits * $10^{+/-38}$
double	8	64	±16 significant digits * $10^{+/-308}$

- Prefer double over float
  - Many compilers will upgrade floats to doubles anyhow
- Don't use floating-point if you don't need to
  - It suffers from rounding error
  - Some additional time overhead to perform arithmetic operations

Text

- Text characters are usually represented with some kind of binary code (mapping of character to a binary number such as 'a' = 01100001 bin = 97 dec)
- ASCII = Traditionally an 8-bit code
  - How many combinations (i.e. characters)?
  - English only
- UNICODE = 16-bit code
  - How many combinations?
  - Most languages w/ an alphabet
- In C/C++ a single printing/text character must appear between single-quotes (')
  - Example: 'a', '!', 'Z'



ASCII printable characters

32	space	64	@	96	`
33	!	65	A	97	a
34	"	66	B	98	b
35	#	67	C	99	c
36	$	68	D	100	d
37	%	69	E	101	e
38	&	70	F	102	f
39	'	71	G	103	g
40	(	72	H	104	h
41	)	73	I	105	i
42	*	74	J	106	j
43	+	75	K	107	k
44	,	76	L	108	l
45	-	77	M	109	m
46	.	78	N	110	n
47	/	79	O	111	o
48	0	80	P	112	p
49	1	81	Q	113	q
50	2	82	R	114	r
51	3	83	S	115	s
52	4	84	T	116	t
53	5	85	U	117	u
54	6	86	V	118	v
55	7	87	W	119	w
56	8	88	X	120	x
57	9	89	Y	121	y
58	:	90	Z	122	z
59	;	91	[	123	{
60	<	92	\	124	|
61	=	93	]	125	}
62	>	94	^	126	~
63	?	95	_		

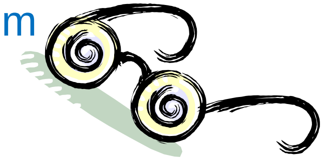
http://www.theasciicode.com.ar/

Interpreting Binary Strings

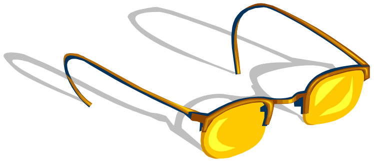
- Given a string of 1’s and 0’s, you need to know the *representation system* being used, before you can understand the value of those 1’s and 0’s.
- Information (value) = Bits + Context (System)
  - Types provide the context (system)

01000001 = ?

Unsigned Binary system



65_{10}



ASCII system

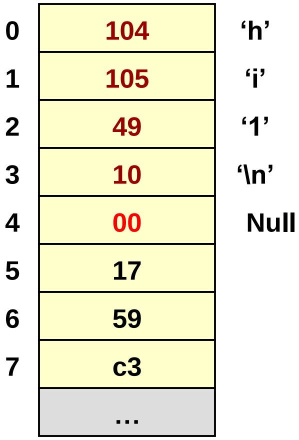
‘A’$_{\text{ASCII}}$

MODULE 2: CONSTANTS, VARIABLES, AND EXPRESSIONS

Constants

- Integer: `496, 10005, -234`
- Double: `12.0, -16., 0.23, -2.5E-1, 4e-2`
- Characters (char type): enclosed in single quotes
  - Printing characters: `'a', '5', 'B', '!'`
  - Non-printing special characters use "escape" sequence (i.e. preceded by a \ ): `'\n'` (newline/enter), `'\t'` (tab) , `'\\'` (slash), `'\''` (apostrophe)
- C-Strings
  - 0 or more characters between double quotes

    `"hi1\n", "12345", "b", "\tAns. is %d"`
  - Ends with a `'\0'`=NULL character added as the last byte/character to allow code to delimit the end of the string
- Boolean (C++ only): `true, false`
  - Physical representation: 0 = false, (Non-zero) = true



0	104	‘h’
1	105	‘i’
2	49	‘1’
3	10	‘\n’
4	00	Null
5	17	
6	59	
7	c3	
	...	

String Example

(Memory Layout)

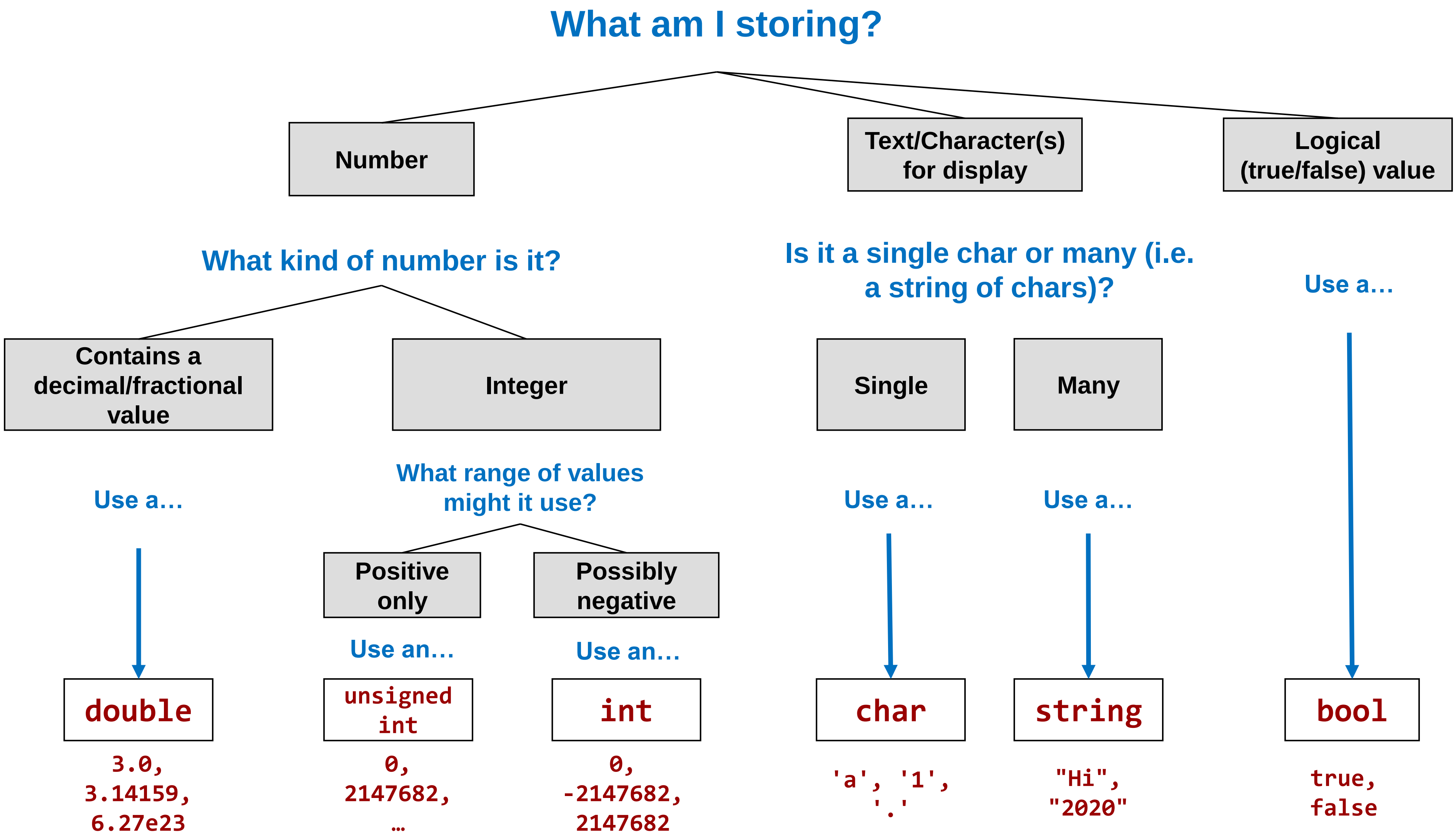
You're Just My Type

- Indicate which constants are matched with the correct type.

Constant	Type	Right / Wrong
4.0	int	
5	int	
'a'	string	
"abc"	string	
5.	double	
5	char	
"5.0"	double	
'5'	int	

Solutions are provided at the end of the slide packet.

What's Your Type



What am I storing?

Number

Text/Character(s) for display

Logical (true/false) value

What kind of number is it?

Contains a decimal/fractional value

Integer

Use a…

double

3.0,
3.14159,
6.27e23

What range of values might it use?

Positive only

Use an…

unsigned int

0,
2147682,
…

Possibly negative

Use an…

int

0,
-2147682,
2147682

Is it a single char or many (i.e. a string of chars)?

Single

Use a…

char

'a', '1',
'.'

Many

Use a…

string

"Hi",
"2020"

Use a…

bool

true,
false

EXPRESSIONS & VARIABLES

Arithmetic Operators

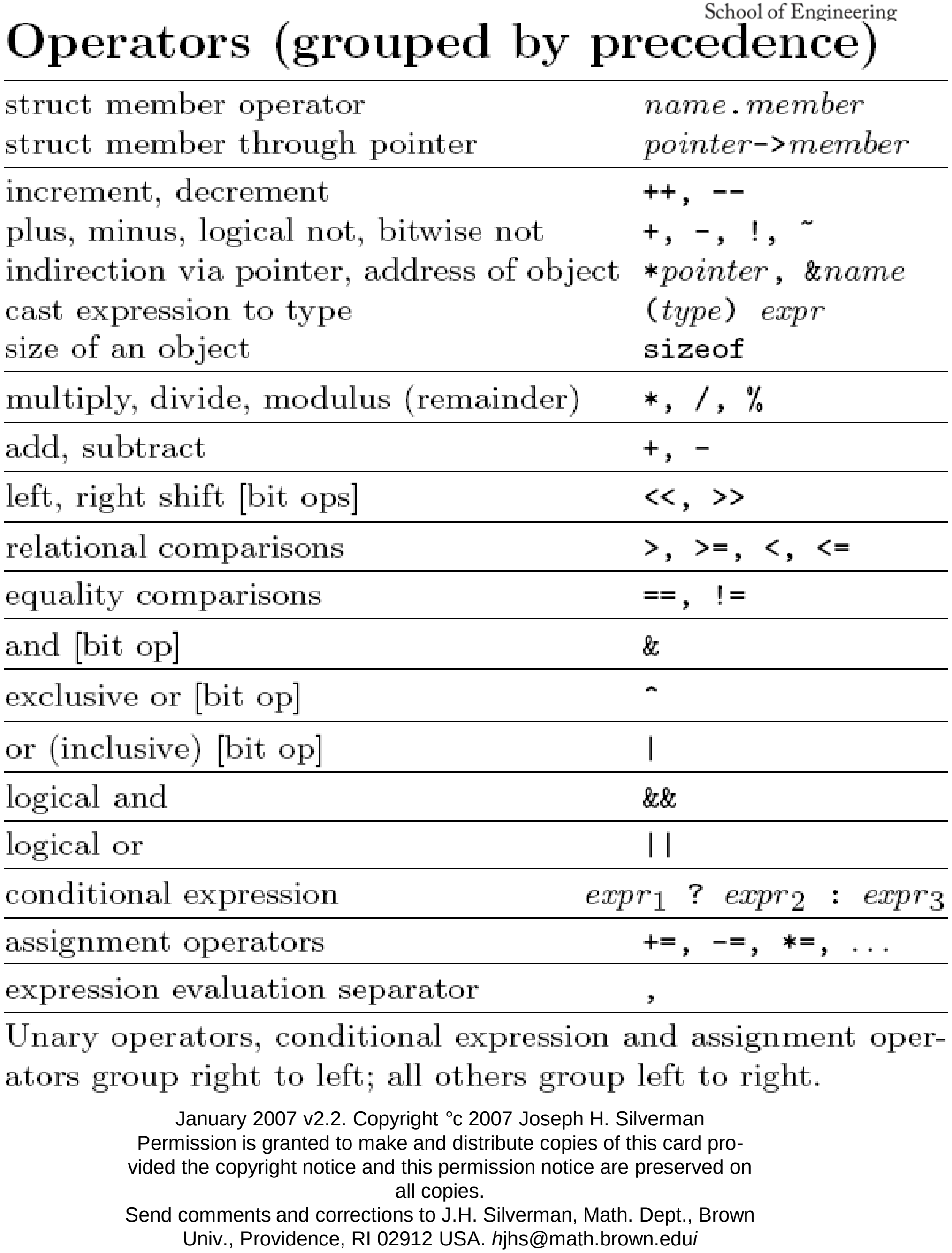
- Addition, subtraction, multiplication work as expected for both integer and floating point types
- Division works ‘differently’ for integer vs. doubles/floats
- Modulus is only defined for integers

Operator	Name	Example
+	Addition	2 + 5
-	Subtraction	41 - 32
*	Multiplication	4.23 * 3.1e-2
/	Division (Integer vs. Double division)	10 / 3 (=3) 10.0 / 3 (=3.3333)
%	Modulus (remainder) [for integers only]	17 % 5 (result will be 2)

```
17 % 10 = __
 4 %  7 = __
```

Precedence

- Order of operations/ evaluation of an expression
- Top Priority = highest (done first)
- Notice operations with the same level or precedence usually are evaluated left to right (explained at bottom)
- Evaluate:
  - `2*-4-3+5/2;`
- Tips:
  - Use parenthesis to add clarity
  - Add a space between literals `(2 * -4) - 3 + (5 / 2)`



Operators (grouped by precedence)

struct member operator	*name*.*member*
struct member through pointer	*pointer*->*member*
increment, decrement	++, --
plus, minus, logical not, bitwise not	+, -, !, ~
indirection via pointer, address of object	**pointer*, &*name*
cast expression to type	(*type*) *expr*
size of an object	sizeof
multiply, divide, modulus (remainder)	*, /, %
add, subtract	+, -
left, right shift [bit ops]	<<, >>
relational comparisons	>, >=, <, <=
equality comparisons	==, !=
and [bit op]	&
exclusive or [bit op]	^
or (inclusive) [bit op]	|
logical and	&&
logical or	||
conditional expression	$expr_1$? $expr_2$: $expr_3$
assignment operators	+=, -=, *=, ...
expression evaluation separator	,

Unary operators, conditional expression and assignment operators group right to left; all others group left to right.

Send comments and corrections to J.H. Silverman, Math. Dept., Brown Univ., Providence, RI 02912 USA. *hjhs@math.brown.edui*

Division

- Computers perform division differently based on the type of values used as inputs
- **Integer** Division:
  - When dividing two integral values, the result will also be an integer (any remainder/fraction will be dropped)
  - 10 / 4 = 2 52 / 10 = 5 6 / 7 = 0
- **Floating-point** (Double) & Mixed Division
  - 10.0 / 4.0 = 2.5 52.0 / 10 = 5.2 6 / 7.0 = 0.8571
  - Note: If one input is a double, the other will be promoted temporarily to compute the result as a double

Exercise Review

- Evaluate the following:
  - `25 / 3`
  - `17 + 5 % 2 – 3`
  - `28 - 5 / 2.0`

Exercises from: D.S. Malik, C++ Programming, 5th Ed., Ch. 2, Q6.

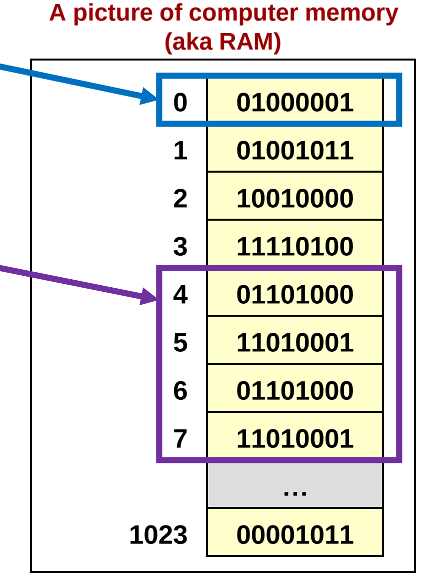
C/C++ Variables

- Variables allow us to
  - **Store a value until it is needed and change its value potentially many times**
  - **Associate a descriptive name with a value**
- Variables are just memory locations that are reserved to store one piece of data of specific size and type
- Programmer indicates what variables they want when they write their code
  - Difference: C requires declaring all variables at the beginning of a function before any operations. C++ relaxes this requirement.
- The computer will allocate memory for those variables as the program runs
- We can provide initial values via '=' or leave them uninitialized

```
#include <iostream>
using namespace std;

int main()
{ // Sample variable declarations
  char c = 'A';
  int x;   // uninitialized variables
           // will have a (random) garbage
           // value until we initialize it
  x = 1;   // Initialize x's value to 1
  c = 'B'; // Change c's value to 'B'
}
```

char c = 'A';
A single-byte variable

int x;
A four-byte variable



A picture of computer memory (aka RAM)

0	01000001
1	01001011
2	10010000
3	11110100
4	01101000
5	11010001
6	01101000
7	11010001
	…
1023	00001011

Variables are actually allocated in RAM when the program is run

C/C++ Variables

- Variables have a:
  - type [`int, char, unsigned int, float, double`, etc.]
  - name/identifier that the programmer will use to reference the value in that memory location [e.g. `x, myVariable, num_dozens`, etc.]
    - Identifiers must start with [A-Z, a-z, or an underscore '_'] and can then contain any alphanumeric character [0-9, A-Z, a-z, _] (but no punctuation other than underscores)
    - Use descriptive names (e.g. numStudents, doneFlag)
    - Avoid cryptic names (myvar1, a_thing)
  - location [the address in memory where it is allocated]
  - Value
- Reminder: You must declare a variable before using it

What's in a name?

To give descriptive names we often need to use more than 1 word/term. But we can't use spaces in our identifier names. Thus, most programmers use either camel-case or snake-case to write compound names

Camel case: Capitalize the first letter of each word (with the possible exception of the first word)

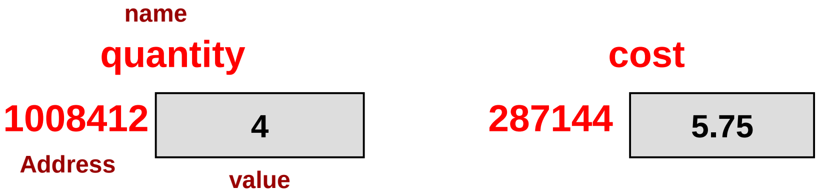
myVariable, isHighEnough

Snake case: Separate each word with an underscore '_'

my_variable, is_high_enough

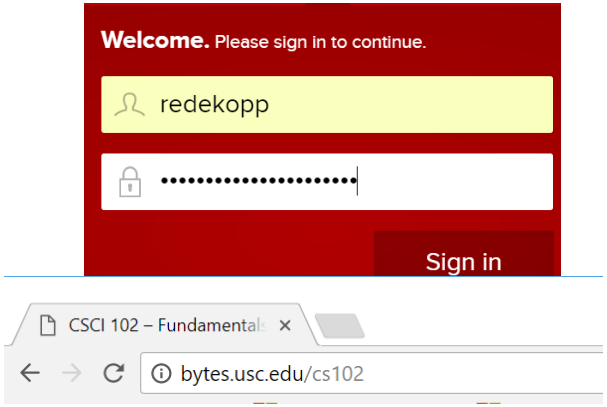
Code

```
int quantity = 4;
double cost = 5.75;
cout << quantity*cost << endl;
```



When To Introduce a Variable

- When a value will be supplied and/or change at run-time (as the program executes)



Welcome. Please sign in to continue.

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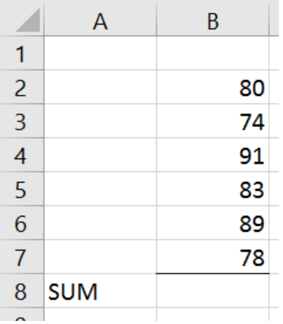
- When a value is computed/updated at one time and used (many times) later



	A	B
1		
2		80
3		74
4		91
5		83
6		89
7		78
8	SUM	

- To make the code more readable by another human

```
double a = (56+34) * (81*6.25);

// readability of above vs. below

double height = 56 + 34;
double width =  81 * 6.25;
double area = height * width;
```

Assignment operator ‘=‘

- Syntax:

```
variable = expression;
```

(LHS) (RHS)

```
int x = 0;
x = x + 3;
```

new-value of x
(3)

current-value of x
(0)

  - LHS = Left Hand-Side, RHS = Right Hand Side
- Should be read: Place the value of *expression* into memory location of *variable*
  - `z = x + y - (2*z);`
  - Evaluate RHS first, then place the result into the variable on the LHS
  - If variable is on both sides, we use the old/current value of the variable on the RHS
- **Note**: Without assignment values are computed and then forgotten
  - `x + 5;` // will take x's value add 5 but NOT update x (just throws the result away)
  - `x = x + 5;` // will actually updated x (i.e. requires an assignment)
- Shorthand assignment operators for updating a variable based on its current value: `+=, -=, *=, /=, &=, …`
  - `x += 5;      (x = x+5)`
  - `y *= x;      (y = y*x)`

Evaluate 5 + 3/2

- The answer is 6.5 ??

Casting

- To achieve the correct answer for 5 + 3 / 2
- Could make everything a double
  - Write 5.0 + 3.0 / 2.0 [explicitly use doubles]
- Could use **implicit** casting (mixed expression)
  - Could just write 5 + 3.0 / 2
    - If operator is applied to mixed type inputs, less expressive type is automatically promoted to more expressive (int is promoted to double)
- Could use C or C++ syntax for **explicit** casting
  - `5 + (double) 3 / (double) 2` (C-Style cast)
  - `5 + static_cast<double>(3) / static_cast<double>(2)` (C++-Style)
  - `5 + static_cast<double>(3)  /  2` (cast one & rely on implicit cast of the other)
  - This looks like a lot of typing compared to just writing `5 + 3.0 / 2`…but what if instead of constants we have variables
  - `int x=5, y=3, z=2;     x + y/z;`
  - `x + static_cast<double>(y)  /  z`

cout and cin

MODULE 3: C++ I/O (INPUT/OUTPUT)

I/O Streams

- I/O is placed in temporary buffers/streams by the OS/C++ libraries
- cin goes and gets data from the input stream (skipping over preceding whitespace then stopping at following whitespace)
- cout puts data into the output stream for display by the OS (a flush forces the OS to display the contents immediately)

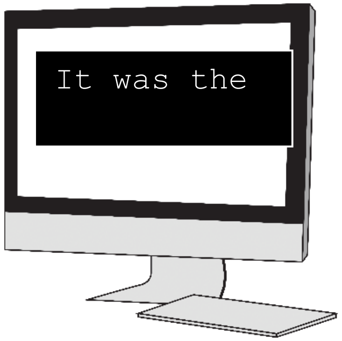
7	5		y	...

input stream:

```
#include<iostream>
using namespace std;
int main()
{
  cout << "It was the" << endl;
  cout << "best of times.";
}
```

output stream:

I	t		w	a	s		t	h	e	\n	b



```
It was the
```

output stream:

4

```
#include<iostream>
using namespace std;
int main()
{
  int x;
  cin >> x;
  return 0;
}
```

input stream:

	y	...

C++ Output

- Include `<iostream>` (not iostream.h)
- Add `using namespace std;` at top of file
- Use an appropriate `cout` statement
- '`cout`' requires appropriate use of separators **<<** between consecutive values or different types of values
- '`cout`' does not add spaces between consecutive values; you must do so explicitly
  - Since text strings are a different value we must separate it with the '<<' operator
- Generally good practice to give some descriptive text with your numeric output
  - Note: You may divide up output over multiple '`cout`' statements. Unless an '`endl`' or '`\n`' is used the next '`cout`' statement will resume where the last one left off

```
#include<iostream>
using namespace std;

int main(int argc, char *argv[])
{
  int x = 5;
  char c = 'Y';
  double y = 4.5;

  cout << "Hello world" << endl;
  cout << "x = " << x;
  cout << " c = " << c << "\ny is "
       << y << endl;
  return 0;
}
```

Output from program:

```
Hello world
x = 5 c = Y
y is 4.5
```

C++ Input

- cin (character input) object used to accept input from the user and write the value into a variable
  - Use the '>>' operator to separate any number of variables or constants you want to read in
  - Every '>>' will skip over any leading whitespace looking for text it can convert to the variable form, then stop at the trailing whitespace

```
#include <iostream>
#include <string>
using namespace std;
int main(int argc, char *argv[])
{
  int x;
  char c;
  string mystr;
  double y;

  cout << "Enter an integer, character,
string, and double separated by
spaces:" << endl;

  cin >> x >> c >> mystr >> y;

  cout << "x = " << x << " c = ";
  cout << c << "mystr is " << mystr;
  cout << "y is " << y << endl;
  return 0;
}
```

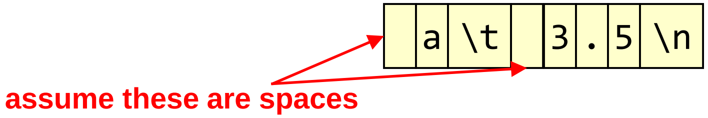
Output from program:

```
Enter an integer, character, string, and double separated by spaces:
5 Y hi 4.5
x = 5 c = Y mystr is hi y is 4.5
```

cin

c = `0` **y =** `0.0`

- If the user types in



	a	\t		3	.	5	\n

assume these are spaces

- After the first '>>'

c = `'a'` **y =** `0.0`

\t		3	.	5	\n

- After the second '>>'

c = `'a'` **y =** `3.5`

\n

```
#include<iostream>
using namespace std;

int main()
{
  char c = 0;
  double y = 0.0;

  cin >> myc;
  cin >> y;
  // use the variables somehow...
  return 0;
}
```

`cin` will:

- skip leading whitespace
- stop at trailing whitespace

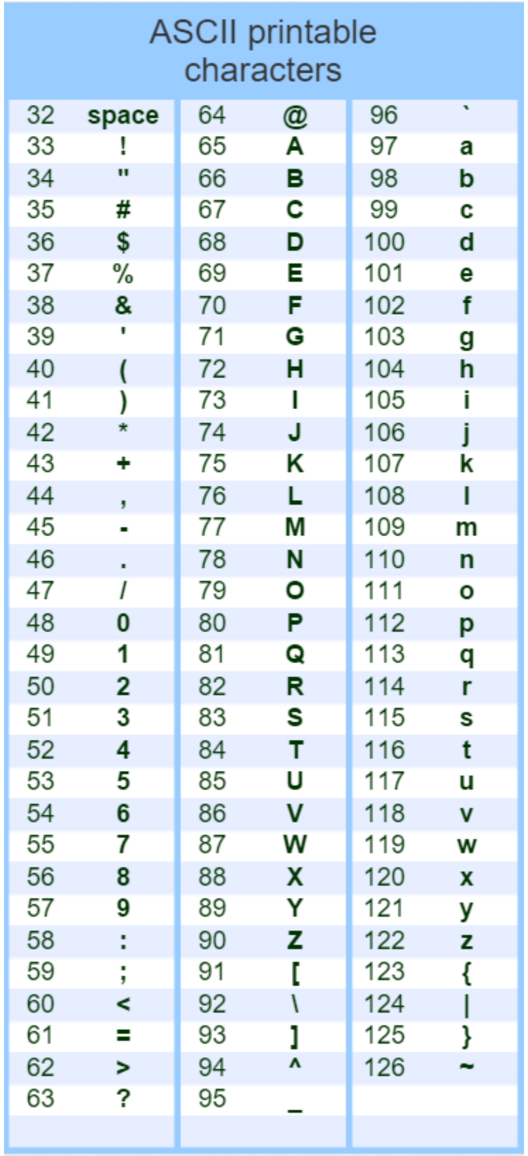
Understanding ASCII and chars

- Characters can still be treated as numbers

char c

97

```
char c = 'a';       // same as  char c = 97;
char d = 'a' + 1;   // c now contains 'b' = 98;
cout << d << endl; // I will see 'b' on the screen

char c = '1';       // c contains decimal 49, not 1
                    // i.e. '1' not equal to 1

c >= 'a' && c <= 'z'; // && means AND
                      // here we are checking if c is
                      // storing a lower case letter
```



ASCII printable characters

32	space	64	@	96	`
33	!	65	A	97	a
34	"	66	B	98	b
35	#	67	C	99	c
36	$	68	D	100	d
37	%	69	E	101	e
38	&	70	F	102	f
39	'	71	G	103	g
40	(	72	H	104	h
41	)	73	I	105	i
42	*	74	J	106	j
43	+	75	K	107	k
44	,	76	L	108	l
45	-	77	M	109	m
46	.	78	N	110	n
47	/	79	O	111	o
48	0	80	P	112	p
49	1	81	Q	113	q
50	2	82	R	114	r
51	3	83	S	115	s
52	4	84	T	116	t
53	5	85	U	117	u
54	6	86	V	118	v
55	7	87	W	119	w
56	8	88	X	120	x
57	9	89	Y	121	y
58	:	90	Z	122	z
59	;	91	[	123	{
60	<	92	\	124	|
61	=	93	]	125	}
62	>	94	^	126	~
63	?	95	_		

In-Class Exercises

- Checkpoint 1

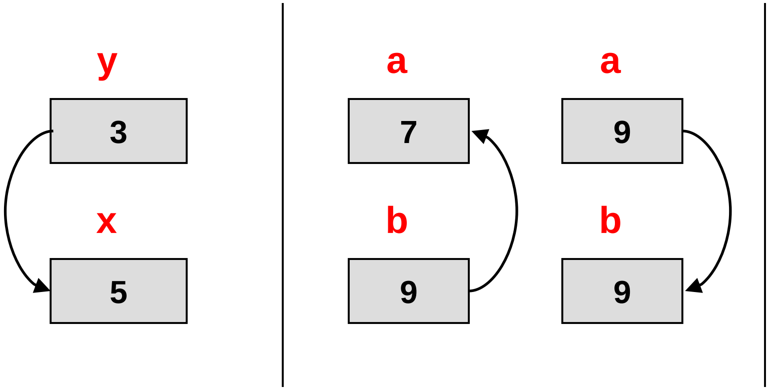
MODULE 4: ODDS & ENDS (LIBRARY FUNCTIONS, ASSIGNMENT, AND CASTING)

Assignment Means Copy

- Assigning a variable makes a copy
- Challenge: Swap the value of 2 variables

```
int main()
{
  int x = 5, y = 3;
  x = y;   // copy y into x

  return 0;
}
```

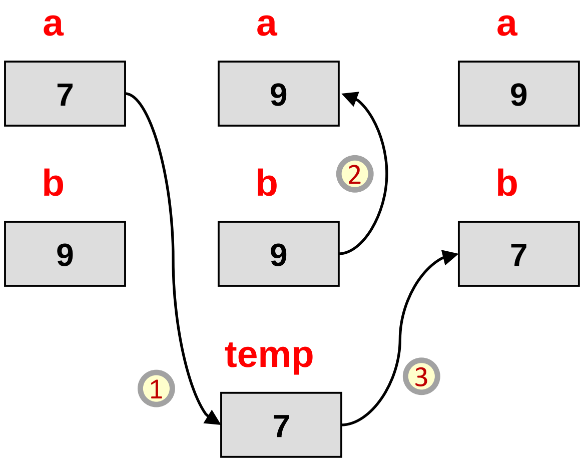
```
int main()
{
  int a = 7, b = 9;

  // now consider swapping
  // the value of 2 variables
  a = b;
  b = a;

  return 0;
}
```



More Assignments

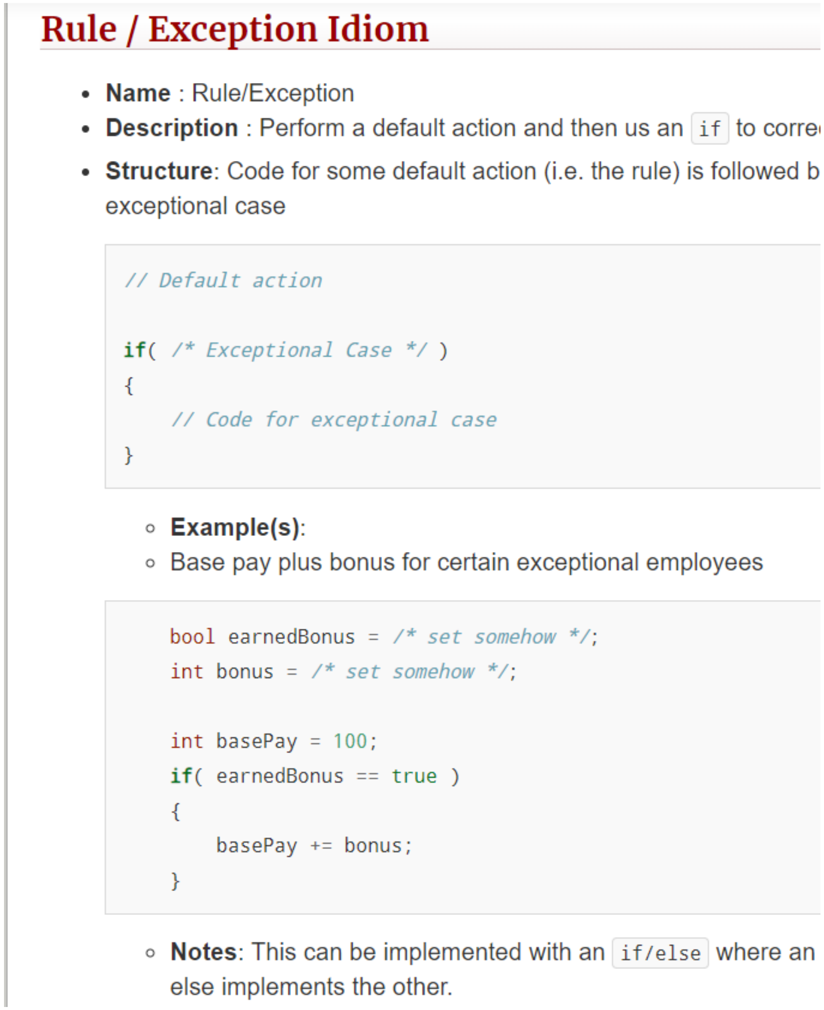
- Assigning a variable makes a copy
- Challenge: Swap the value of 2 variables
  - – Easiest method: Use a 3rd temporary variable to save one value and then replace that variable

```
int main()
{
 int a = 7, b = 9, temp;

 // let's try again
 temp = a;
 a = b;
 b = temp;

  return 0;
}
```



Problem Solving Idioms

- An idiom is a colloquial or common mode of expression
  - Example: "raining cats and dogs"
- Programming has common modes of expression that are used quite often to solve problems algorithmically
- We have developed a repository of these common programming idioms. We STRONGLY suggest you
  - Reference them when attempting to solve programming problems
  - Familiarize yourself with them and their structure until you feel comfortable identifying them



Rule / Exception Idiom

- **Name** : Rule/Exception
- **Description** : Perform a default action and then us an `if` to corre
- **Structure**: Code for some default action (i.e. the rule) is followed b exceptional case

```
// Default action

if( /* Exceptional Case */ )
{
    // Code for exceptional case
}
```

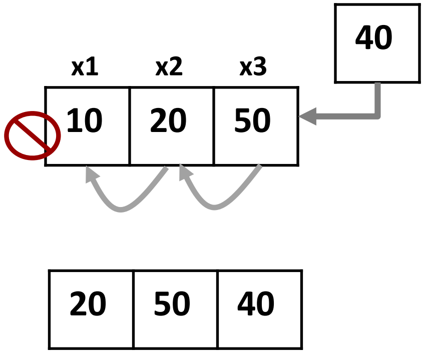
- **Example(s)**:
- Base pay plus bonus for certain exceptional employees

```
    bool earnedBonus = /* set somehow */;
    int bonus = /* set somehow */;

    int basePay = 100;
    if( earnedBonus == true )
    {
        basePay += bonus;
    }
```

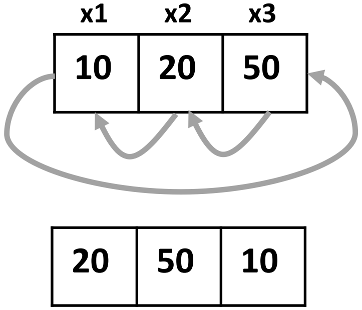
- **Notes**: This can be implemented with an `if/else` where an else implements the other.

Assignment Idioms: Shifting and Rotation

- The **shifting idiom** shifts data among variables usually replacing/dropping some elements to make room for new ones
  - The key pattern is some elements get **dropped/overwritten** and other elements are **reassigned/moved**
  - It is important to **start by assigning the variable to be replaced/dropped** and then move in order to variables receiving newer data
  - Examples: Top k items (high score list)
- The **rotation idiom** reorders or rearranges data among variables without replacing/dropping elements
  - The key pattern is **all elements are kept** but just reordered
  - It is usually necessary to declare and **maintain some temporary variable** to avoid elements getting dropped/overwritten



Shifting Idiom



Rotation Idiom

A Few Odds and Ends

- Variable Initialization
  - When declared they will have "garbage" (random or unknown) values unless you initialize them
  - Each variable must be initialized separately
- Scope
  - Global variables are visible to ***all*** the code/functions in the program and are declared ***outside*** of any function
  - Local variables are declared ***inside*** of a function and are ***only*** visible in that function and ***die*** when the function ends

```
/*----Section 1: Compiler Directives ----*/
#include <iostream>
#include <cmath>
using namespace std;

// Global Variables
int x;  // Anything after "//" is ignored

int add_1(int input)
{
  // y and z not visible here, but x is
  return (input + 1);
}

int main(int argc, char *argv[])
{
  // y and z are "local" variables
  int y, z=5; // y is garbage, z is five

  z = add_1(z);
  y = z+1;    // an assignment stmt
  cout << y << endl;
  return 0;
}
```

Math & Other Library Functions

- C++ predefines a variety of functions for you. Here are a few of them:
  - sqrt(x): returns the square root of x (in <cmath>)
  - pow(x, y): returns x^y, or x to the power y (in <cmath>)
  - sin(x)/cos(x)/tan(s): returns the trig. Function's value for x if x is in radians (in <cmath>)
  - abs(x): returns the absolute value of x (in <cstdlib>)
  - max(x, y) and min(x,y): returns the maximum/minimum of x and y (in <algorithm>)
- You call these by writing them similarly to how you would use a function in mathematics [using parentheses for the inputs (aka) arguments]
- Result is replaced into bigger expression
- Must #include the correct library
  - #includes tell the compiler about the various pre-defined functions that your program may choose to call

```
#include <iostream>
#include <cmath>
#include <algorithm>
using namespace std;

int main()
{
  // can call functions
  //  in an assignment
  double res = cos(0); // res = 1.0

  // can call functions in an
  //  expression
  res =  sqrt(2) / 2; // res = 1.414/2

  cout << max(34, 56) << endl;
  // outputs 56

  return 0;
}
```

http://www.cplusplus.com/reference/cmath/

Statements

- C/C++ programs are composed of statements
- Most common kinds of statements end with a semicolon
- Declarations (e.g. `int x=3;`)
- Assignment + Expression (suppose **int x=3; int y;**)
  - `x = x * 5 / 9;` // compute the expression & place result in x
    `// x = (3*5)/9 = 15/9 = 1`
- Assignment + Function Call (+ Expression)
  - `x = cos(0.0) + 1.5;`
  - ~~`sin(3.14)`~~`;` // Must save or print out the result (x = sin(3.14), etc.)
- cin, cout statements
  - `cout << cos(0.0) + 1.5 << " is the answer." << endl;`
- Return statement (immediately ends a function)
  - `return` *`value`*`;`

Pre- and Post-Increment Operators

- ++ and -- operators can be used to "increment-by-1" or "decrement-by-1"
  - If ++ comes before a variable it is call pre-increment; if after, it is called post-increment
  - `x++; // If x was 2 it will be updated to 3 (x = x + 1)`
  - `++x; // Same as above (no difference when not in a larger expression)`
  - `x--; // If x was 2 it will be updated to 1 (x = x – 1)`
  - `--x; // Same as above (no difference when not in a larger expression)`
- Difference between pre- and post- is only evident when used in a larger expression
- Meaning:
  - Pre: Update (inc./dec.) the variable before using it in the expression
  - Post: Use the old value of the variable in the expression then update (inc./dec.) it
- Examples [suppose we start each example with: `int y; int x = 3;`]
  - `y = x++ + 5;  // Post-inc.; Use x=3 in expr. then inc. [y=8, x=4]`
  - `y = ++x + 5;  // Pre-inc.; Inc. x=4 first, then use in expr. [y=9, x=4]`
  - `y = x-- + 5;  // Post-dec.; Use x=3 in expr. then dec. [y=8, x=2]`

In-Class Exercises

- Checkpoint 2

SOLUTIONS

You're Just My Type

- Indicate which constants are matched with the correct type.

Constant	Type	Right / Wrong
4.0	int	double (.0)
5	int	int
'a'	string	char
"abc"	string	C-string
5.	double	float/double (. = non-integer)
5	char	Int…but if you store 5 in a char variable it'd be okay (char = some number that fits in 8-bits/1-byte
"5.0"	double	C-string
'5'	int	char