CS 103 Unit 3a – Objects Intro: Structs and Strings

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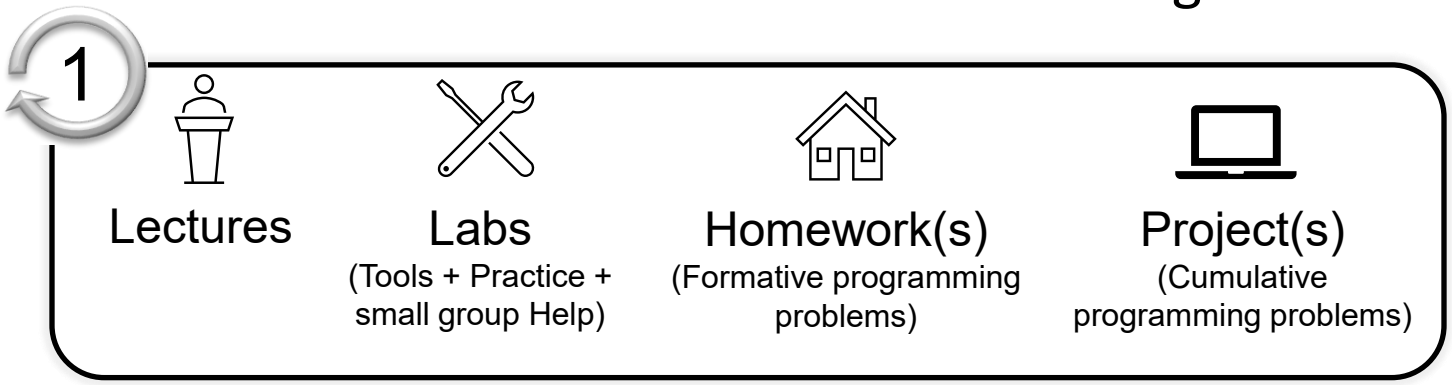
Course Structure

- The course is broken into 6 units each consisting of:



C++ Language Syntax

Pointers and Memory

Objects 1

Managing Data

Objects 2

Recursion

Make arbitrary integer codes more readable

ENUMERATIONS

Enumerations

- Associates an integer (number) with a symbolic name
- `enum [optional_collection_name] {Item1, Item2, … ItemN}`
  - Item1 = 0
  - Item2 = 1
  - …
  - ItemN = N-1
- Use symbolic item names in your code and compiler will replace the symbolic names with corresponding integer values

```
const int BLACK=0;
const int BROWN=1;
const int RED=2;

const int WHITE=7;


int pixela = RED;
int pixelb = BROWN;
...
```

Hard coding symbolic names with given codes

```
// First enum item is associated with 0
enum Colors {BLACK,BROWN,RED,...,WHITE};

int pixela = RED;   // pixela = 2;
int pixelb = BROWN; // pixelb = 1;
```

Using enumeration to simplify

Use enumerations to make related integer codes/constants more readable.

```
enum {CSCI, CSBA, CECS, CSGM, AMCM, QBIO};

int major = AMCM;   // major = 4;

int minor = CSCI;   // minor = 0;
```

OBJECTS

Review: Program Decomposition

- C is a **procedural** language
  - A **function** or **procedure** is the primary unit of code organization, problem decomposition, and abstraction
  - **Functions** can be reused across many applications
- C++ is considered an **object-oriented** language (adds objected-oriented constructs to C) though still supports a procedural approach
  - A **class** or **object** is the primary unit of code organization, problem decomposition, and abstraction
  - Can be reused

Exercise

- To decompose a program into **functions**, try listing the ***verbs*** or ***tasks*** that are performed to solve the problem
  - Model a card game as a series of tasks/procedures…
  - A database representing a social network
- To decompose a program into **objects**, listen for the ***nouns***, ***objects***, or agents that are interacting

Object-Oriented Approach

- Model the application/software as a set of objects that interact with each other
- Objects fuse data (i.e. variables) and functions (a.k.a methods) that operate on that data into one entity
- Objects replace global-level functions as the primary method of encapsulation and abstraction
  - Encapsulation: Code + data together with controlled access
    - Group data and code that operates on that data together into one unit
    - Only expose a well-defined interface to control misuse of the code by other programmers
  - Abstraction
    - Hiding of data and implementation details
    - How we decompose the problem and think about our design at a higher level rather than considering everything at the lower level

Objects

- Often times we want to represent higher level concepts, objects, or things (beyond an integer, character, or double)
  - Examples: a pixel, a circle, a student, a file
- These "objects" can be represented as a collection of integers, character arrays/strings, etc.
  - A pixel (with R,G,B value)
  - A circle (center_x, center_y, radius)
  - A student (name, ID, major)
- Objects (embodied as 'structs' in C and later 'classes' in C++) allow us to aggregate different type variables together to represent a single larger 'thing' as well as supporting operations on that 'thing'
  - Can reference the collection with a single name (myCircle, student1)
  - Can access individual components (myCircle.radius, student1.id)

Motivation for Objects

- When going to the airport, would you rather carry all your luggage items piecemeal or pack everything in one suitcase?

```
void process(char name[], int id, int major)
{

}
```

```
void process(Student s1)
{

}
```

s1

Object-Oriented Programming

- Objects contain:
  - Data members
    - Data needed to model the object and track its state/operation (just like structs)
  - Methods/Functions
    - Code that operates on the object, modifies it, etc.
- Example: Deck of cards
  - Data members:
    - Array of 52 entries (one for each card) indicating their ordering
    - Top index
  - Methods/Functions
    - `shuffle(), cut(), get_top_card()`

C++ Objects: Structs vs. Classes

- Structs (originated in the C language) are the predecessors of classes (C++ language)
  - Though structs are still valid in C++ and now behave almost EXACTLY the same as a class (i.e. struct/class are nearly interchangeable)
- Classes form the basis of object-oriented programming in the C++ language
- Both are simply a way of *grouping* related **data** together and related **operations** (functions or methods) to model some 'object'
  - We'll look at structs now, and classes a bit later, but recall they are interchangeable. So pay attention now to make subsequent lectures easier.

Starting with data…

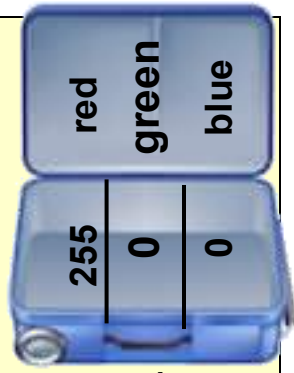
STRUCTS

Types and Instances

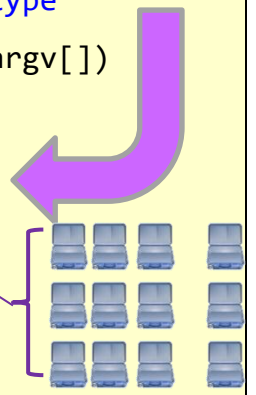
- A 'type' indicates **how much memory** will be required, **what the bits mean** (i.e. integer, double, pointer), and **what operations** can be performed
  - **int** = 32-bits representing only integer values and supporting `+`, `-`, `*`, `/`, `=`, `==`, `<`, `>`, etc.
  - **char*** = 64-bits representing an address and supporting * (dereference), `&`, `+`, `-` (but not multiply and divide)
  - Types are like **blueprints** for what & how to make a particular 'thing'
- A 'variable' or 'object' is an actual instantiation (allocation of memory) for one of these types
  - `int x, double z, char *str;`

Definitions and Instances (Declarations)

- Objects must first be defined/declared (as a 'struct' or 'class')
  - The declaration is a blueprint that indicates what any instance should look like
  - Identifies the overall name of the struct and its individual member types and names
  - The declaration does not actually create a variable (no memory is allocated)
  - Usually appears outside any function
- Once declared, any number of instances can be created/instantiated in your code
  - ***Instances*** are actual objects (memory is allocated for each) created from the definition (blueprint)
  - Declared like other variables



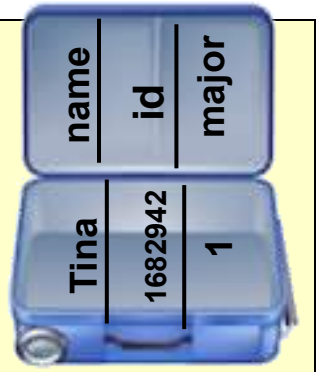

```
#include <iostream>

using namespace std;

// struct definition
struct pixel {
  unsigned char red;
  unsigned char green;
  unsigned char blue;
};
// 'pixel' is now a type
//  just like 'int' is a type

int main(int argc, char *argv[])
{
  int i,j;
  // instantiations
  pixel p1;
  pixel image[256][256];
  // make p1 red
  p1.red = 255;
  p1.blue = p1.green = 0;
  // make a green image
  for(i=0; i < 256; i++){
    for(j=0; j < 256; j++){
      image[i][j].green = 255;
      image[i][j].blue = 0;
      image[i][j].red = 0;
  }  }
  return 0;
}
```



Membership Operator (.)

- Each variable (and function) in an object definition is called a member of the object (i.e. struct or class)
- When declaring an instance/variable of an object, we give the entire object a name, but the individual members are identified with the member names provided earlier in the object definition
- We use the . (dot/membership) operator to access that member in an instance of the object
  - Supply the name used in the definition above so that code is in the form: **`instance_name.member_name`**

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

enum {CSCI=1, CECS=2};

struct student {
  char name[80];
  int id;
  int major;
};

int main(int argc, char *argv[])
{
  int i,j;
  // instantiations
  student my_student;

  // how would you set their name to
  // "Tina"

  ____________________________________

  my_student.id = 1682942;
  my_student.major = CSCI;
  ...
  return 0;
}
```

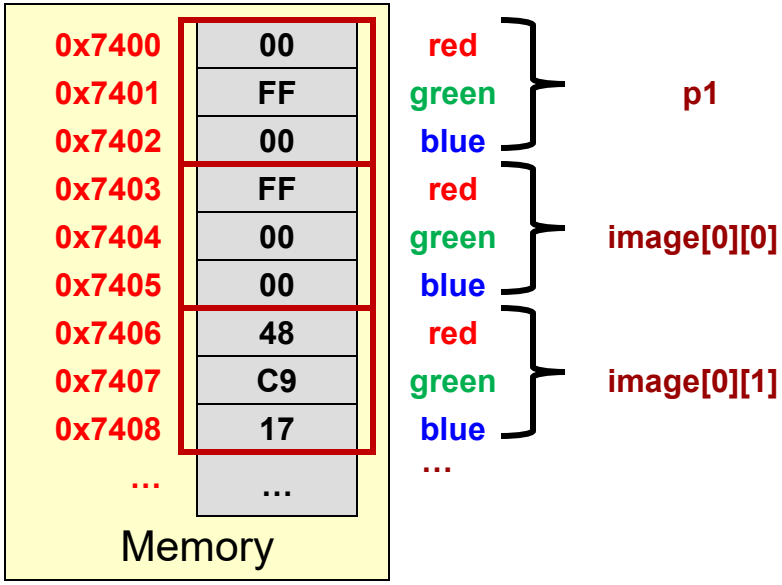


mystudent

Memory View of Objects

- Each instantiation allocates memory for all the members/components of the object (struct or class)

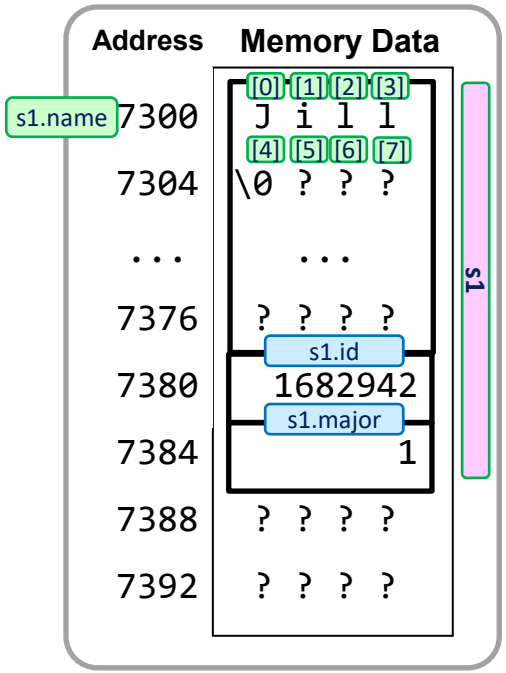
```
#include<iostream>

using namespace std;
// declaration (blueprint)
struct pixel {
  unsigned char red;
  unsigned char green;
  unsigned char blue;
};
int main(int argc, char *argv[])
{
  int i,j;
  // instantiations (object allocation)
  pixel p1;
  pixel image[256][256];
...
  return 0;
}
```



Memory View of Objects

- Objects can have data members that are arrays or even other objects

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

// declaration (blueprint)
struct student {
  char name[80];
  int id;
  int major;
};
int main(int argc, char *argv[])
{
  int i,j;
  // instantiation (object allocation)
  student s1;
  ...
  return 0;
}
```



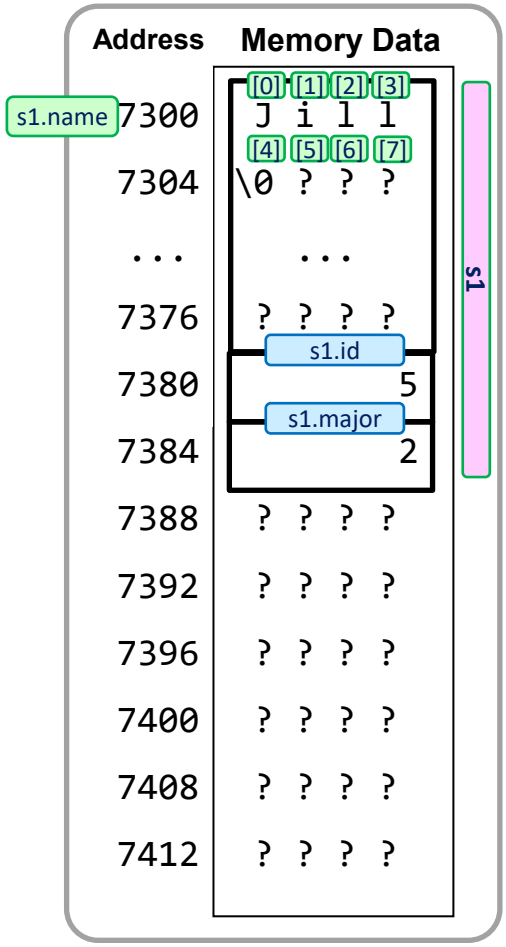
Assignment semantics and pointers to objects

IMPORTANT NOTES ABOUT OBJECTS

Object assignment

- Consider the following initialization of s1

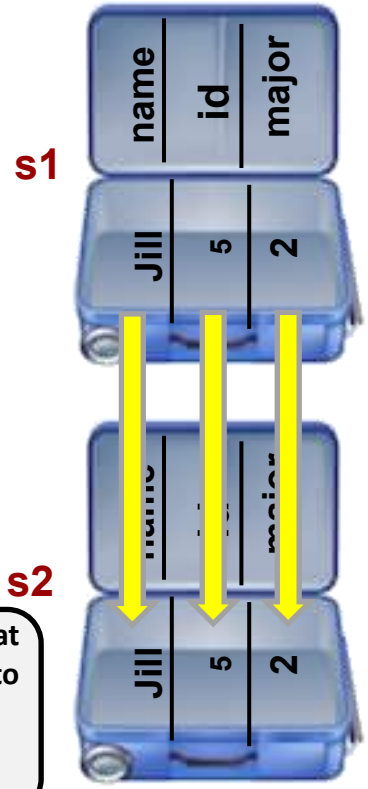
```
#include<iostream>
using namespace std;

enum {CSCI=1, CECS};

struct student {
  char name[80];
  int id;
  int major;
};

int main(int argc, char *argv[])
{
  student s1,s2;
  strncpy(s1.name,"Jill",80);
  s1.id = 5; s1.major = CECS;
```

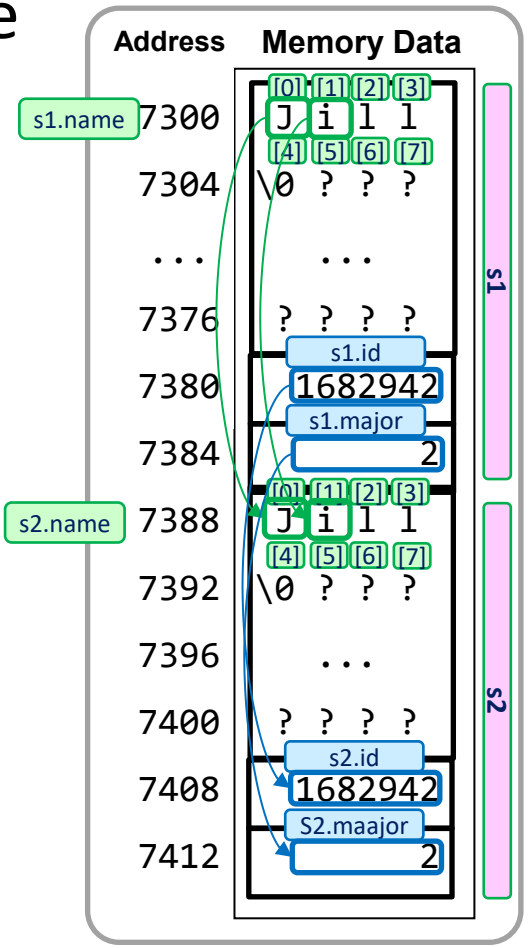


Object assignment

- Assigning one object to another will perform a **member-by-member copy** of the entire source object to the destination object

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

enum {CSCI=1, CECS };

struct student {
  char name[80];
  int id;
  int major;
};

int main(int argc, char *argv[])
{
  student s1,s2;
  strncpy(s1.name,"Jill",80);
  s1.id = 5; s1.major = CECS;
  s2 = s1;
  return 0;
}
```



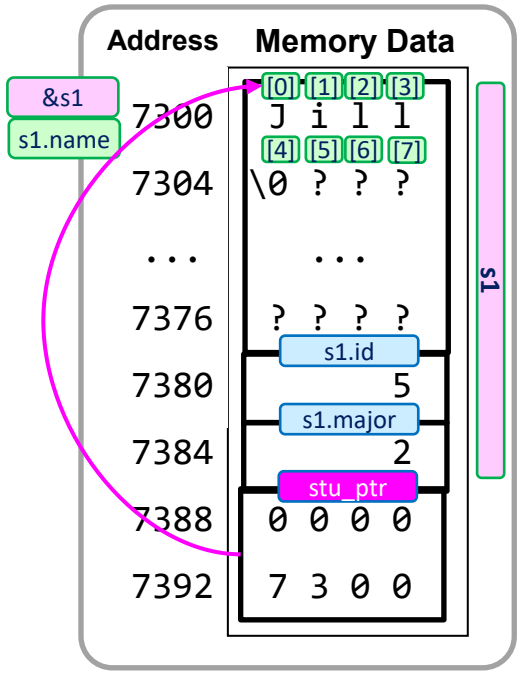


Normally, C/C++ perform only one operation at a time, and make you write code if you want to do more. But object assignment is an exception (probably because we can't "loop through" the different members of a struct).

Pointers to Objects

- We can declare **pointers** to objects just as any other variable
- The address of a struct is just (you guessed it) its starting address

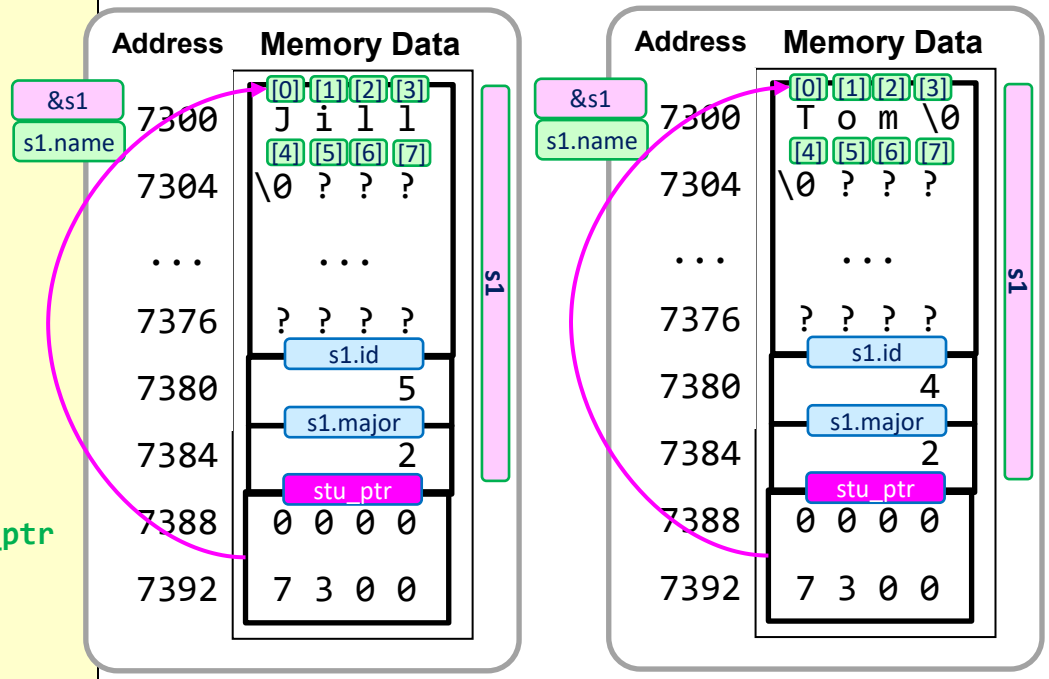
```
#include<iostream>
using namespace std;
enum {CSCI=1, CECS };
struct student {
  char name[80];
  int id;
  int major;
};

int main(int argc, char *argv[])
{
  student s1;
  student *stu_ptr;
  strncpy(s1.name,"Jill",80);
  s1.id = 5; s1.major = CECS;
  stu_ptr = &s1;
  return 0;
}
```



Accessing members from a Pointer

- Can dereference the pointer first then use the dot operator
- Unfortunately . has higher precedence than * requiring you to use parenthesis

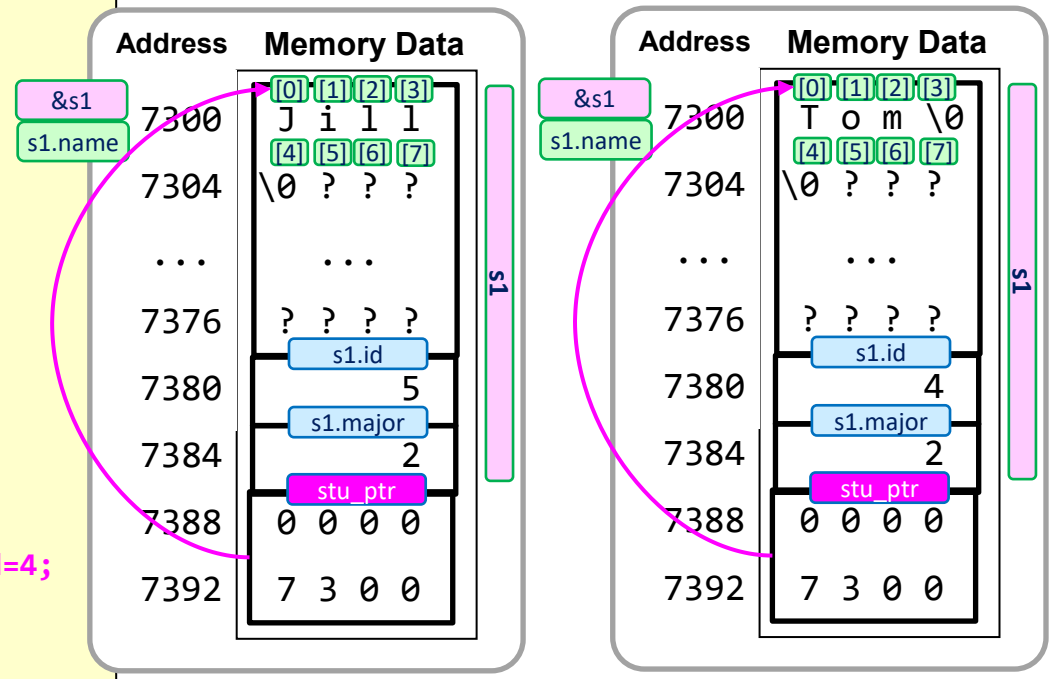
```
#include<iostream>
using namespace std;

enum {CSCI=1, CECS };

struct student {
  char name[80];
  int id;
  int major;
};

int main(int argc, char *argv[])
{
  student s1, *stu_ptr;
  strncpy(s1.name,"Jill",80);
  s1.id = 5; s1.major = CECS;
  stu_ptr = &s1;

  *stu_ptr.id = 4;     // incorrect – derefs id
  (*stu_ptr).id = 4;   // correct – derefs stu_ptr
  strncpy( (*stu_ptr).name, "Tom",80);


  return 0;
}
```



Arrow (->) operator

- Save keystrokes & have cleaner looking code by using the arrow (->) operator
  - `(*struct_ptr).member` equivalent to `struct_ptr->member`
  - Always of the form: `ptr_to_struct->member`

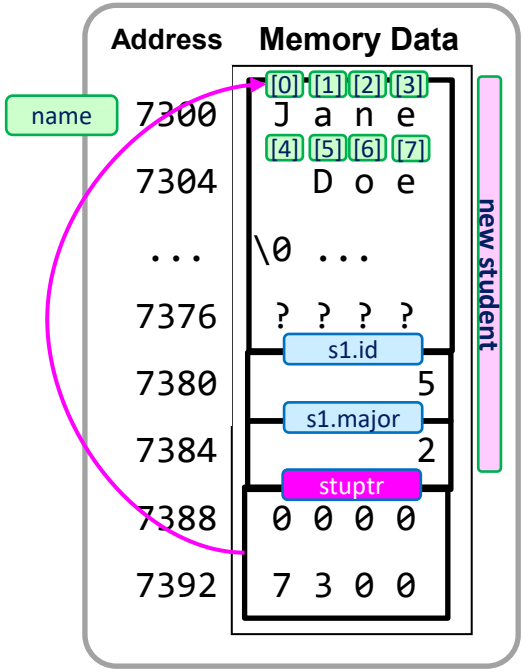
```
#include<iostream>
using namespace std;

enum {CSCI=1, CECS };

struct student {
  char name[80];
  int id;
  int major;
};

int main(int argc, char *argv[])
{
  student s1, *stu_ptr;
  strncpy(s1.name,"Jill",80);
  s1.id = 5; s1.major = CECS;
  stu_ptr = &s1;

  stu_ptr->id = 4;    // same as (*stu_ptr).id=4;
  strncpy( stu_ptr->name, "Tom",80);

  return 0;
}
```



When Are Pointers To Objects Used?

```
#include<iostream>
using namespace std;
enum {CSCI=1, CECS };

struct student {
  char name[80];
  int id;
  int major;
};
student* makeStudent(const char* n, int i, int m)
{
  student* stuptr = new student;

  strncpy(stuptr->name, n, 80);
  stuptr->id = i; stuptr->major = m;
  return stuptr;
}

int main()
{
  student* stuptr =
        makeStudent("Jane Doe", 5, CECS);
  ...
  cout << stuptr->name << endl;
         // prints "Jane Doe"
  delete stuptr;
  return 0;
}
```

- Pointers to objects occur commonly when objects are passed by reference or dynamically allocated



Passing Objects as Arguments

- In C, arguments must be a single value [i.e. can't pass an entire array of data, instead pass a pointer]
- Objects are the exception…you can pass an entire struct 'by value'
  - Will make a member-by-member copy of the struct and pass it to the function
- Of course, you can always pass a pointer [especially for big objects since pass by value means making a copy of a large objects]

```
#include<iostream>

using namespace std;

struct Point {
  int x;
  int y;
};

void print_point(Point myp)
{
  cout << "(x,y)=" << myp.x << "," << myp.y;
  cout << endl;
}

int main(int argc, char *argv[])
{
  Point p1;
  p1.x = 2; p1.y = 5;
  print_point(p1);
  return 0;
}
```

Returning Objects

- Can return a struct from a function
- Will return a ***copy*** of the struct indicated
  - i.e. 'return-by-value'

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

struct Point {
  int x;
  int y;
};
void print_point(Point *myp)
{
  cout << "(x,y)=" << myp->x << "," << myp->y;
  cout << endl;
}
Point make_point()
{
  Point temp;
  temp.x = 3; temp.y = -1;
  return temp;
}
int main(int argc, char *argv[])
{
  Point p1;
  p1 = make_point();
  print_point(&p1);
  return 0;
}
```

C++ STRINGS

Motivation

- Before we dive deeper into writing our OWN objects…
- …Let's learn how to use objects (structs/classes) that the C++ library already provides us.
- One of the most basic (and useful) objects in the C++ library is the `string` class.
- To understand what they do for you (and how they provide "encapsulation" and "abstraction", let's review how we dealt with strings in C (i.e. before the `string` class existed)

Review: C Strings

- In C, strings are:
  - Character arrays (`char mystring[80];`)
  - Terminated with a NULL character (`'\0'` ⇔ `0`)
  - Passed by reference/pointer (`char *`) to functions
  - Require care when making copies
    - Shallow (only copying the pointer) vs. Deep (copying the entire array of characters)
  - Processed using C String library (`<cstring>`)

String Function/Library (cstring)

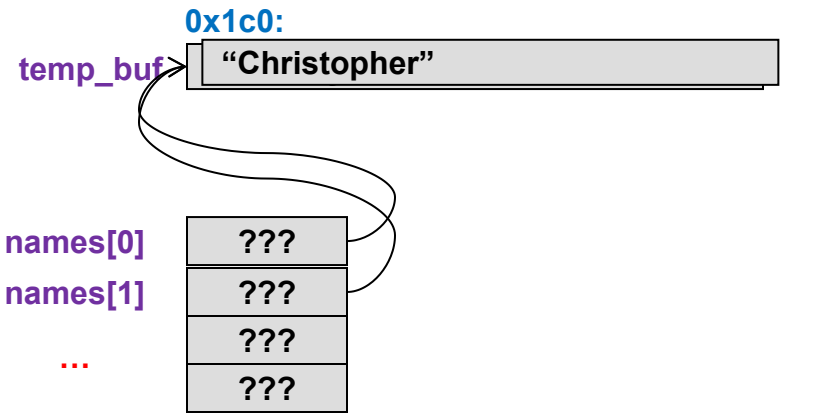
In C, we have to pass the C-String as an argument for the function to operate on it

- int strlen(char *dest)
- int strcmp(char *str1, char *str2);
  - Return 0 if equal, >0 if first non-equal char in str1 is alphanumerically larger, <0 otherwise
- char *strcpy(char *dest, char *src);
  - strncpy(char *dest, char *src, int n);
  - Maximum of n characters copied
- char *strcat(char *dest, char *src);
  - strncat(char *dest, char *src, int n);
  - Maximum of n characters concatenated plus a NULL
- char *strchr(char *str, char c);
  - Finds first occurrence of character ‘c’ in str returning a pointer to that character or NULL if the character is not found

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

int main() {
  char temp_buf[5];
  char str[] = "Too much";

  strcpy(temp_buf, str); // bad
  return 0;

}
```

Review: Shallow vs. Deep C-String Copy

- Recall our conversation of shallow vs. deep copies
- Can we just use the assignment operator, '=' with character arrays?
  - No, must allocate new storage

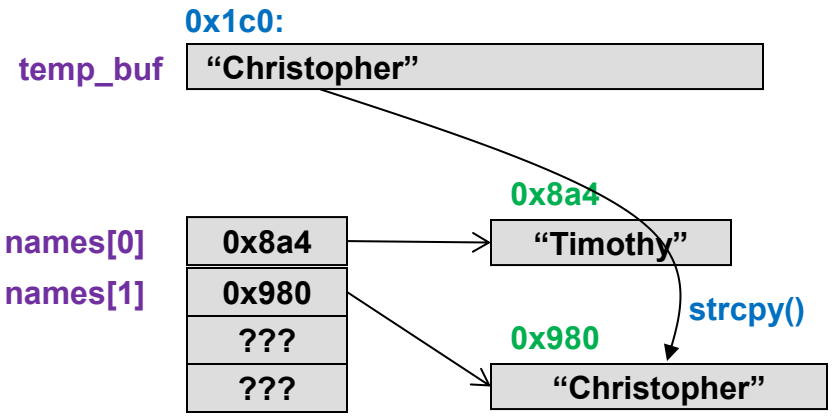


Assigning an array name just assigns a pointer and does NOT make a copy of the array.

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

int main()
{
  // store 10 user names
  //   names type is still char **
  char* names[10];

  // One "scratchpad" array for all inputs
  char temp_buf[40];

  for(int i=0; i < 10; i++){
    cin >> temp_buf;
    names[i] = temp_buf;
  }
  // Do stuff with names

  for(int i=0; i < 10; i++){
    delete [] names[i];
  }
  return 0;
}
```

More Dealing with Text Strings

- Must allocate new storage




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


int main()
{
  // store 10 user names
  //   names type is still char **
  char* names[10];

  char temp_buf[40];
  for(int i=0; i < 10; i++){
    cin >> temp_buf;
    // Find length of strings
    int len = strlen(temp_buf);
    names[i] = new char[len + 1];
    strcpy(names[i], temp_buf);

  }

  // Do stuff with names


  for(int i=0; i < 10; i++){
    delete [] names[i];
  }

  return 0;
}
```

C++ Strings

- So you don't like remembering all these details?
  - You can do it! Don't give up.
- C++ provides a 'string' class that **abstracts** all those worrisome details and **encapsulates** all the code to actually handle:
  - Memory allocation and sizing
  - Deep copy
  - Concatenation, Comparison, Size information
  - etc.

C++ Strings

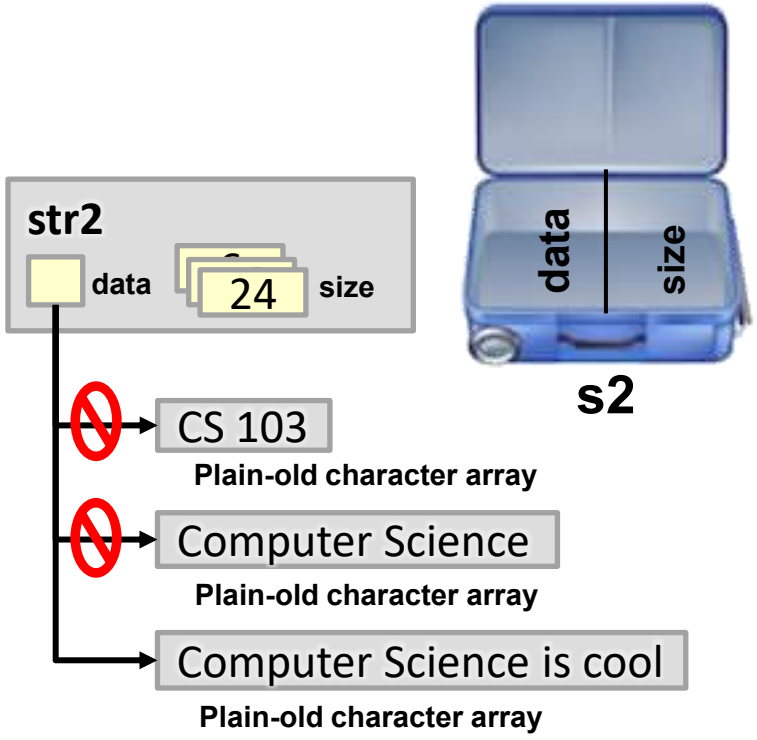
- In C++, the **string** class provides an easier alternative to working with plain-old **character arrays**
- Do's and Don'ts
  - **Do** `#include <string>` and put `using namespace std;`
  - **Do** initialize using **=** or by giving an initial value in parentheses (aka use the "constructor" syntax)
  - **Don't** need to declare the size (i.e. `[7]`), just assign
  - **Do** still use it like an array by using **`[index]`** to get individual characters
  - **Do** still use `cin/cout` with strings
  - **Don't** worry about how many characters the user types when inputting to a C++ string

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

int main()
{
  char str1[7] = "CS 103";
  /* Initializes the array to "CS 103" */
  string str2 = "CS 103";
  string str3("Hello");   // constructor
  /* Initializes str2 to "CS 103" &
                  str3 to "Hello" */

  str2[5] = '4'; // now str2 = "CS 104"

  cout << str2 << endl;
                // prints "CS 104"

  cin >> str1; // If the user types more
                // than 6 chars..uh oh!
  cin >> str2; // str2 will adjust to
                // hold whatever the user
                // types
}
```

What Happens Behind the Scenes

- Strings simply abstract character arrays
- Behind the scenes strings are just creating and manipulating character arrays but giving you a simplified set of operators and functions
- Can concatenate (append) to a string with the + operator

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

int main()
{
  string str2 = "CS 103";
  // str2 stores 6 chars. = "CS 103"

  str2 = "Computer Science";
  // now str2 stores 16 characters

  // Can append using '+' or '+=' operator
  str2 = str2 + " is cool";
  // now str2 stores 24 characters
}
```



String Comparison

- C++ strings will perform lexicographic (alphabetical) comparison when comparison operators (<, >, ==, etc.) are applied
- Comparison operators **do not work** with plain old character arrays

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

int main()
{
  char str1[4] = "abc";
  string str2 = "abc";

  if( str1 == "abc" ) // doesn't work
    {...}
  if( str2 == "abc" ) // works..true
    {...}

  if( str1 < "aac" )  // doesn't work
    {...}
  if( str2 < "aac" )  // works..false
    {...}

  string str3 = "acb";

  if( str3 > str2 )   // works..true
    {...}
}
```

Calling Member Functions (Methods)

- Use the dot operator to call an operation (function) on an object or access a data value
- Asking for the string size
  - Call the `.size()` function on a string to get the number of characters stored in the string
- Can generate substrings
  - Call either of the 2 versions:
    `.substr(start_index)` **or**
    `.substr(start_index, length)`
    function on the string
- Many more member functions

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

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

int main()
{
  string mystr = "CS 103";
  cout << mystr.size() << endl; // 6

  string s = mystr.substr(2);
     // s = "103"

  mystr = "Computer Science";
  cout << mystr.size() << endl; // 16

  s = mystr.substr(9,2);
    // s = "Sc"

}
```

Other Member Functions

- Get C String (char *) equiv.
- Find a substring
  - Searches for occurrence of a substring
  - Returns either the index where the substring starts or string::npos
  - std::npos is a constant meaning 'just beyond the end of the string'…it's a way of saying 'Not found'
- Others: replace, rfind, etc.

```
#include <iostream>
#include <string>
#include <cstring>
using namespace std;
int main( )
{
  string s1("abcdef");
  char my_c_str[80];

  strcpy(my_c_str, s1.c_str() );
  cout << my_c_str << endl;

  size_t idx = s1.find("bcd");
  if(idx != string::npos){
    cout << "Found bcd starting at pos=":
    cout << idx << endl;
  }
  else {
    cout << "Not found" << endl;
  }
  return 0;
}
```

Output:

```
abcdef
Found bcd starting at pos=1
```

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

String ⇔ Number Conversion

- Recall: Casting does **NOT** work for string ⇔ numeric conversions.
- Instead, use functions defined in `<string>`
- Conversion from number to string:
  - `string to_string(int);`
  - `string to_string(double);`
  - `...`
- Conversion from string to number:
  - `int stoi(string);`
  - `unsigned int stoul(string);`
  - `double stod(string);`

```
#include <iostream>
#include <string>
using namespace std;
int main() {

 double a = 3.6;
 int b = static_cast<int>(a) / 2;
    // Works! b = 1 (casts 3.6 to 3)

 int c = 123;
 string d = static_cast<string>(c);
    // Error! Doesn't compile.
 string d = to_string(c);
    // Works! But only since C++11

 string e = "42";
 int f = static_cast<int>(e);
   // Error! Doesn't compile.
 int f = stoi(e);  // string-to-int
   // Works! But only since C++11
   // use stod() for string-to-double
 return 0;
}
```

Summary

- You've already used objects
  - iostream (cin and cout)
  - Now file streams and strings
  - There will be many more objects we can use from the C++ library
- Can initialize at declaration by passing initial value in ( )
  - Known as a constructor
- Use the **dot operator** to call an operation (function) on an object or access a data value
- Some special operators can be used on certain object types
  (+, -, [], etc.) but you have to look them up

```
#include <iostream>
#include <fstream>
Using namespace std;

int main()
{
  int x; char line[80];
  ifstream myfile(argv[1]);
  if( ! myfile.fail() ){
    myfile >> x;
  }

  cin.getline(line, 80);
  cout << line << endl;

  return 0;
}
```

cin, cout, ifstreams, and ofstreams are examples of objects

Exercises (If Time Allows)

- Palindrome
- Circular Shift