# Week 4

## Pointers & Dynamic Memory Allocation

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# Pointers and Addresses

- The address operator (&) returns the address of a variable.

```
int x;
cout << &x << endl;    // 0xbffffb0c
```

- Pointer: a variable that stores the address of another variable, providing indirect access to it.
- An asterisk is used to define a pointer variable

```
int *ptr;
```

- "ptr is a pointer to an int". It can contain addresses of int variables.

```
ptr = &x;
```



# Dereferencing and initializing

- The unary operator * is the dereferencing operator.
- *ptr is an alias for the variable that ptr points to.

```
int x = 10;
int *ptr;  //declaration, NOT dereferencing
ptr = &x;  //ptr gets the address of x
*ptr = 7;  //the thing ptr pts to gets 7
```

- Initialization:

```
int x = 10;
int *ptr = &x; //declaration, NOT dereferencing
```

- ptr is a pointer to an int, and it is initialized to the address of x.



# Pointers as Function Parameters

- Use pointers to implement pass by reference.

```
//prototype: void changeVal(int *);

void changeVal (int *val) {
   *val = *val * 11;
}

int main() {
   int x;
   cout << "Enter an int " << endl;
   cin >> x;
   changeVal(&x);
   cout << x << endl;
}
```

- How is it different from using reference parameters?

# Pointers and Arrays

- You can treat an array variable as if it were a pointer to its first element.

```
int numbers[] = {10, 20, 30, 40, 50};

cout << "first: " << numbers[0] << endl;
cout << "first: " << *numbers << endl;

cout << &(numbers[0]) << endl;
cout << numbers << endl;
```

Output:

```
first: 10
first: 10
0xbffffb00
0xbffffb00
```



# Pointer Arithmetic

- When you **add a value n to a pointer**, you are actually adding n times the size of the data type being referenced by the pointer.

```
int numbers[] = {10, 20, 30, 40, 50};

// sizeof(int) is 4.
// Let us assume numbers is stored at 0xbffffb00
// Then numbers+1 is really 0xbffffb00 + 1*4, or 0xbffffb04
// And numbers+2 is really  0xbffffb00 + 2*4, or 0xbffffb08
// And numbers+3 is really  0xbffffb00 + 3*4, or 0xbffffb0c

cout << "second: " << numbers[1] << endl;
cout << "second: " << *(numbers+1) << endl;

cout << "size: " << sizeof(int) << endl;
cout << numbers << endl;
cout << numbers+1 << endl;
```

Output:

```
second: 20
second: 20
size: 4
0xbffffb00
0xbffffb04
```



- **Note: array[index] is equivalent to *(array + index)**

# Pointers and Arrays

- pointer operations can be used with array variables.

```
int list[10];
cin >> *(list+3);
```

- subscript operations can be used with pointers.

```
int list[] = {1,2,3};
int *ptr = list;
cout << ptr[2];
```



# Comparing Pointers

- pointers (addresses) maybe compared using the relational operators:

  `<  <=  >  >=  ==  !=`

- Examples:

```
int arr[25];

cout << (&arr[1] > &arr[0]) << endl;
cout << (arr == &arr[0]) << endl;
cout << (arr <= &arr[20]) << endl;
cout << (arr > arr+5) << endl;
```

- What is the difference?
  - `ptr1 < ptr2`
  - `*ptr1 < *ptr2`

# Dynamic Memory Allocation

- When a function is called, memory for local variables is automatically allocated.
- When a function exits, memory for local variables automatically disappears.
- Must know ahead of time the maximum number of variables you may need.
- Dynamic Memory allocation allows your program to create variables on demand, during run-time.



# The new operator

- "new" operator requests dynamically allocated memory for a certain data type:

```
int *iptr;
iptr = new int;
```

- new operator returns address of newly created anonymous variable.
- use dereferencing operator to access it:

```
*iptr = 11;
cin >> *iptr;
int value = *iptr / 3;
```



# Dynamically allocated arrays

- dynamically allocate arrays with new:

```
int *iptr;  //for dynamically allocated array
int size;

cout << "Enter number of ints: ";
cin >> size;
iptr = new int[size];

for (int i=1; i<size; i++) {
   iptr[i] = i;
}
```

- Program will throw an exception and terminate if not enough memory available to allocate



# delete!

- When you are finished using a variable created with new, use the delete operator to destroy it:

```
int *ptr;
double *array;

ptr = new int;
array = new double[25];
. . .
delete ptr;
delete [] array;  // note [] required for dynamic arrays!
```

- Do not "delete" pointers whose values were NOT dynamically allocated using new!
- Do not forget to delete dynamically allocated variables (Memory Leaks!!).

# Returning Pointers from Functions

- functions may return pointers:

```
int * findZero (int arr[]) {
   int *ptr;
   ptr = arr;
   while (*ptr != 0)
      ptr++;
   return ptr;
}
```

NOTE: the return type of this function is (int *) or pointer to an int.

- The returned pointer must point to
  - dynamically allocated memory OR
  - an item passed in via an argument

NOTE: if the function returns dynamically allocated memory, then it is the responsibility of the calling function to delete it.



# Returning Pointers from Functions: duplicateArray

```
int *duplicateArray (int *arr, int size) {

   int *newArray;
   if (size <= 0)          //size must be positive
      return NULL;         //NULL is 0, an invalid address

   newArray = new int [size];  //allocate new array

   for (int index = 0; index < size; index++)
      newArray[index] = arr[index];  //copy to new array

   return newArray;
}
```

```
int a [5] = {11, 22, 33, 44, 55};
int *b = duplicateArray(a, 5);
for (int i=0; i<5; i++)
   if (a[i] == b[i])
      cout << i << " ok" << endl;
delete [] b;  //caller deletes mem
```

Output

```
0 ok
1 ok
2 ok
3 ok
4 ok
```



# Pointers to structures

- We can define pointers to structures

```
Student s1 = {12345,"Jane Doe", 18, "Math"};
Student *ptr = &s1;
```

- To access the members via the pointer:

```
cout << *ptr.name << end;     // ERROR: *(ptr.name)
```

- dot operator has higher precedence, so use ():

```
cout << (*ptr).name << end;
```

- or equivalently, use ->:

```
cout << ptr->name << end;
```



# Dynamically Allocating Structures

- Structures can be dynamically allocated with new:

```
Student *sptr;
sptr = new Student;

sptr->name = "Jane Doe";
sptr->idNum = 12345;
...
delete sptr;
```

- Arrays of structures can also be dynamically allocated:

```
Student *sptr;
sptr = new Student[100];
sptr[0].name = "John Deer";
...
delete [] sptr;
```

No arrows (->) necessary. It's just an array of Student