Chapter 10

Pointers & Dynamic Arrays

Pointer Definition

- A pointer contains the memory address of a variable
- You’ve used pointers already
  - Call-by-reference parameters
    - Address of actual argument was passed
- Example:
  double *p;
  - p is declared a "pointer to double" variable
  - Can hold pointers to variables of type double
    - Not other types

Declaring Pointers

- Pointers declared like other types
  - Add "*" before variable name
  - Produces "pointer to" that type
- "*" must be before each variable
- int *p1, *p2, v1, v2;
  - p1, p2 hold pointers to int variables
  - v1, v2 are ordinary int variables

Address of operator

- int *p1, *p2, v1, v2;
  p1 = &v1;
  - Sets pointer variable p1 to "point to" int variable v1
- Operator, &
  - Determines "address of" variable
  - Same operator used in call-by-reference
- Read like:
  - "p1 points to v1"

Dereferencing Pointers

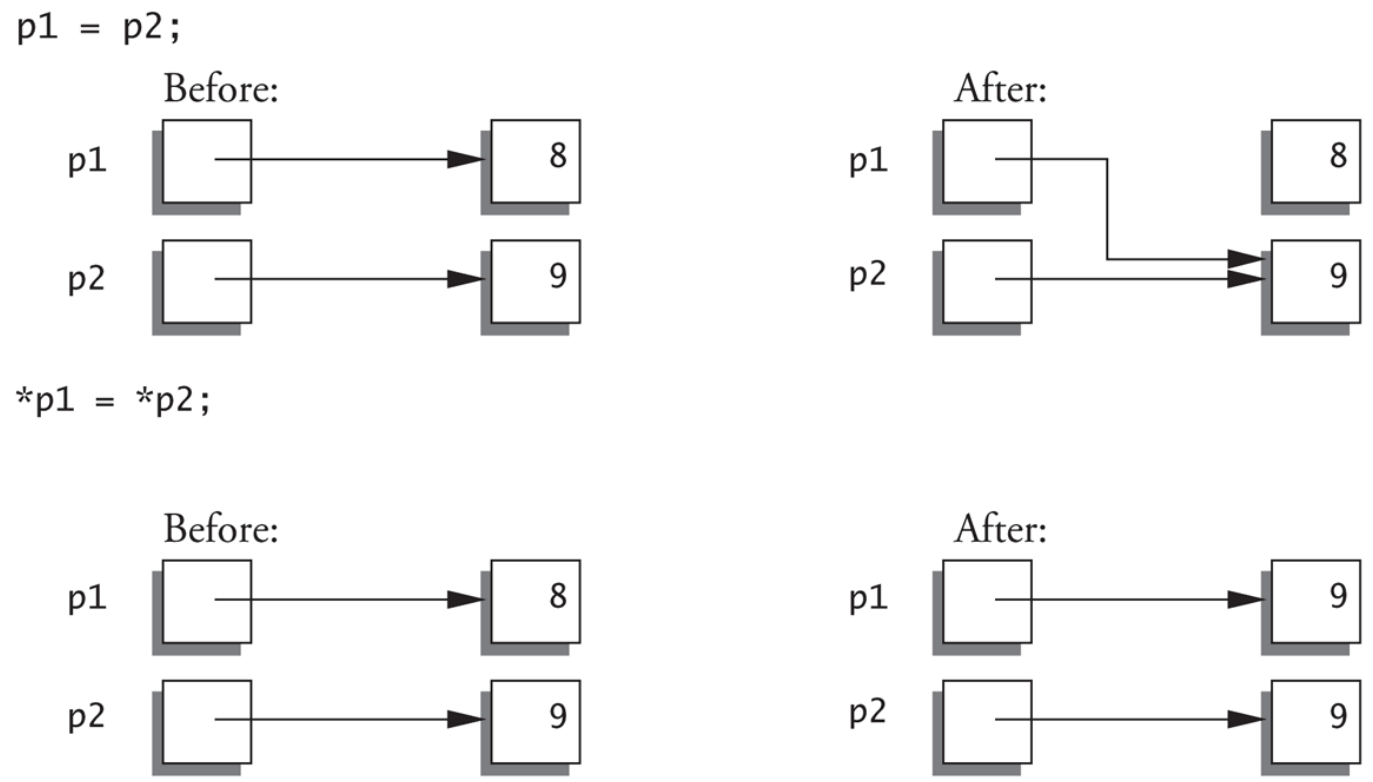
- Recall:
  ```
  int *p1, *p2, v1, v2;
  p1 = &v1;
  ```
- Two ways to refer to v1 now:
  - Variable v1 itself:
    ```
    cout << v1;
    ```
  - Via pointer p1:
    ```
    cout << *p1;
    ```
- Dereference operator, *
  - Pointer variable "de-referenced"
  - Means: "Get data that p1 points to"

Assigning Pointers

- Pointer variables can be "assigned":
  int *p1, *p2;
  p2 = p1;
  - Assigns one pointer to another
  - "Make p2 point to where p1 points"
- Do not confuse with:
  *p1 = *p2;
  - Assigns "value pointed to" by p1, to "value pointed to" by p2

Assignment Example

Display 10.1 **Uses of the Assignment Operator with Pointer Variables**

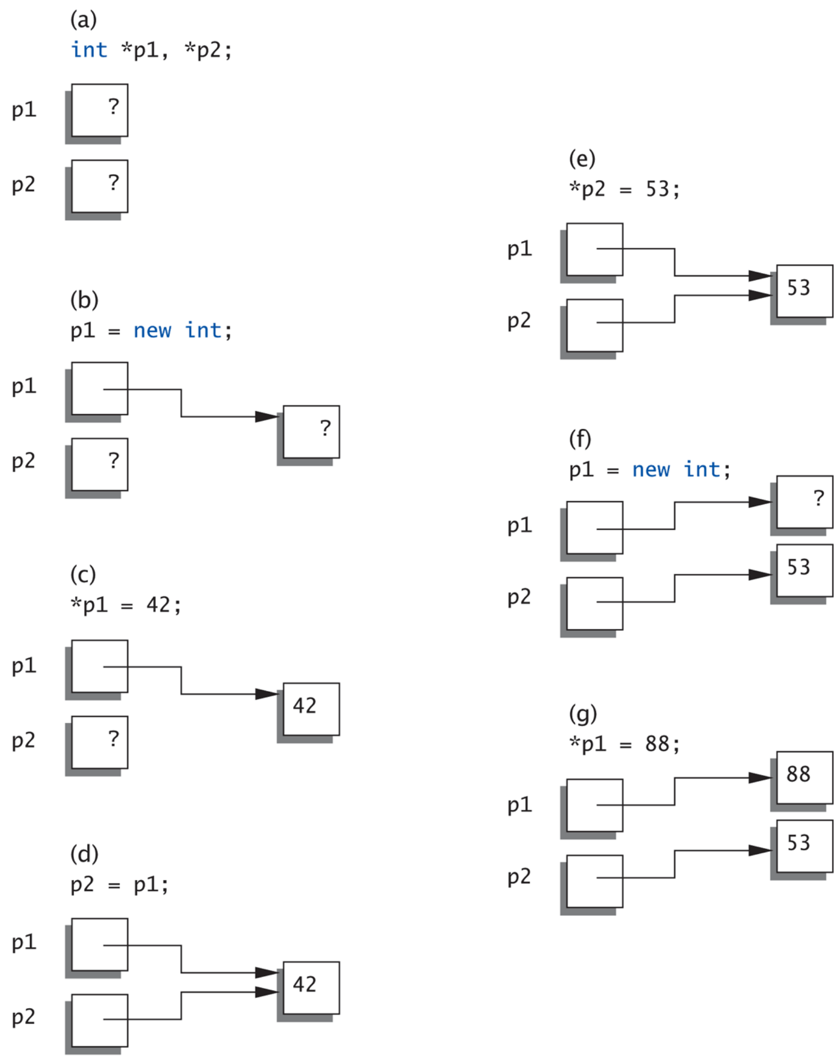


New operator

- Can dynamically allocate variables
  - Operator *new* creates variables
    - No identifiers to refer to them
    - Just a pointer
- p1 = new int;
  - Creates new "nameless" variable, and assigns p1 to "point to" it
  - Can access with *p1
    - Use just like ordinary variable

New Operator Example

Display 10.3 **Explanation of Display 10.2**



More on new operator

- Creates new dynamic variable
- Returns pointer to the new variable
- If type is class type:
  - Constructor is called for new object
  - Can invoke different constructor with initializer arguments:

```
MyClass *mcPtr;
mcPtr = new MyClass(32.0, 17);
```

- Can still initialize non-class types:

```
int *n;
n = new int(17);        //Initializes *n to 17
```

Pointers and Functions

- Can be function parameters
- Can be returned from functions
- This function declaration:

  ```
  int* findOtherPointer(int* p);
  ```

  - Has "pointer to an int" parameter
  - Returns "pointer to an int" variable

Memory Management

- Heap
  - Also called "freestore"
  - Reserved for dynamically-allocated variables
  - All new dynamic variables consume memory in freestore
    - If too many → could use all freestore memory
- Future "new" operations will fail if freestore is "full"

Checking if new succeeded

- Older compilers:
  - Test if null returned by call to *new:*

```
int *p = new int;
if (p == NULL) {
    cout << "Aborting. Insufficient memory.\n";
    exit(1);
}
```

- Newer compilers:
  - If new operation fails:
    - Program terminates automatically
    - Produces error message
  - Still good practice to use NULL check

Freestore Size

- Varies with implementations
- Typically large
  – Most programs won't use all memory
- Memory management
  – Still good practice
  – Solid software engineering principle
  – Memory IS finite
    - Regardless of how much there is

Delete Operator

- De-allocate dynamic memory
  - When no longer needed
  - Returns memory to freestore
  - Example:

```
int *p;
p = new int(5);
… //Some processing…
delete p;
```

  - De-allocates dynamic memory "pointed to by pointer p"

Dangling Pointer

- delete p;
  - Destroys dynamic memory
  - But p still points there!
    - Called "dangling pointer"
  - If p is then dereferenced (*p)
    - Unpredictable results!
    - Often disastrous!
- Avoid dangling pointers
  - Assign pointer to NULL after delete:

```
delete p;
p = NULL;
```

Dynamic & Automatic Variables

- Dynamic variables
  - Created with new operator
  - Created and destroyed while program runs
- Local variables
  - Declared within function definition
  - Not dynamic
    - Created when function is called
    - Destroyed when function call completes
  - Often called "automatic" variables
    - Properties controlled for you

Static vs Dynamic Arrays

- Static arrays
  - int nums[SIZE]
  - Size is known at compile time
  - Fixed size
- Dynamic Arrays
  - int* nums = new int[SIZE]
  - Size is determined at run-time
  - Can grow and shrink as needed

Array Variables

- Arrays are stored sequentially in memory
  - Name of array is address of first element
  - Therefore the name of an array is a pointer
- Example:

```
int a[10];
int* p;
```

  - a and p are both pointers so we can perform assignments

```
p = a;    // p now points to array a
a = p;    // ILLEGAL: a is a constant pointer i.e
          // const int* type
```

Dynamic Arrays

- Estimate initial size and allocate that amt of memory

```
int* nums = new int[size];
```

- When array is full create a bigger one and copy elements

```
int* temp = new int[size + increment];
for (int i = 0; i < size; ++i)
    temp[i] = nums[i];
```

- Delete old array to avoid memory leaks

```
delete [] nums;    // Notice []. Means delete array.
```

- Reassign pointer so new array has same name as old

```
nums = temp;
```

- Update array size

```
size += increment;
```

Returning Arrays

- Array type not allowed as return-type of function
- Example:

```
int [] someFunction();    // Illegal
```

- Instead return pointer to array base type:

```
int* someFunction();    // Legal
```

- This means that the function that created the array is not responsible for deleting it

Pointer Arithmetic

- Can perform arithmetic on pointers
  - "Address" arithmetic
- Example:
  double* d = new double[10];
  - d contains address of d[0]
  - d + 1 evaluates to address of d[1]
  - d + 2 evaluates to address of d[2]
    - Equates to "address" at these locations

Array Manipulation

- Can access elements of an array using
  - Pointer arithmetic

```
for (int i = 0; i < arraySize; ++i)
    cout << *(d + i) << endl;
// OR
int i = 0;
while(i < arraySize) {
    cout << *d << endl;
    d++;
    i++;
}
```

  - Regular array indexing

```
for (int i = 0; i < arraySize; i++)
    cout << d[i] << endl ;
```

- Only addition/subtraction on pointers
  - No multiplication, division

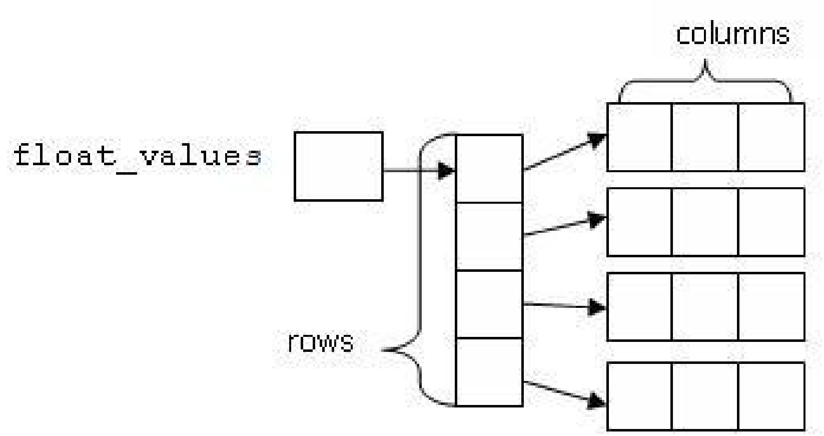
Multi-dimensional Arrays

- Create an "array of arrays"
- To create a 4x3 array:
  - Create an array of 4 pointers (rows)

```
float** float_values = new float*[4];
```

  - Allocate an array of 3 elements to each row pointer

```
for (int i = 0; i < 4; i++)
    float_values[i] = new float[3];
```



Arrow Operator

- The -> operator
  - Shorthand notation
- Combines dereference operator * and dot operator
- Example:

```
MyClass *p = new MyClass;
p->print();
```

- Equivalent to:

```
(*p).print();
```

This pointer

- Member function definitions might need to refer to calling object
- Use predefined **this** pointer
  - Automatically points to calling object:

```
class Simple {
  public:
          void showStuff() const;
  private:
          int stuff;
};
```

- Two ways for member functions to access:

```
cout << stuff;
cout << this->stuff;
```

Destructors

- Opposite of constructor
  - Automatically called when object is out-of-scope
  - Default version only removes static variables
- Must manually delete dynamically-allocated variables
- Defined like constructor, just add ~

```
MyClass::~MyClass() {
    //Delete all dynamically allocated variables
}
```