C++ PROGRAM MEMORY MODEL, POINTERS AND REFERENCES

Problem Solving with Computers-I

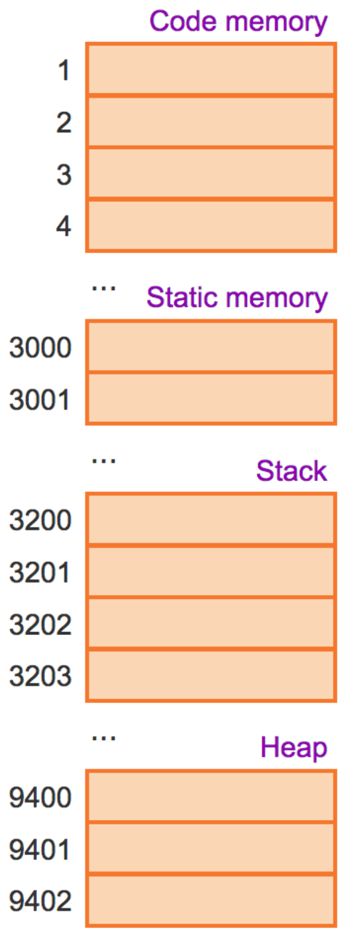
```
#include <iostream>
using namespace std;

int main(){
    cout<<"Hola Facebook\n";
    return 0;
}
```

Learning Goals

- Review basics of classes
  - Defining classes and declaring objects (last lecture)
  - Access specifiers: private, public (last lecture)
  - Different ways of initializing objects and when to use each:
    - Default constructor
    - Parametrized constructor
    - Parameterized constructor with default values
    - Initializer lists
- Develop a mental model of how programs are represented in memory.
- Understand pointer and reference mechanics and how they are used to pass parameters to functions

C++ Memory Model a.k.a Program’s Memory Regions

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

// Program is stored in code memory

int myGlobal = 33;     // In static memory

void MyFct() {
   int myLocal;        // On stack
   myLocal = 999;
   cout << " " << myLocal;
}

int main() {
   int myInt;             // On stack
   int* myPtr = nullptr; // On stack
   myInt = 555;

   myPtr = new int;       // In heap
   *myPtr = 222;
   cout << *myPtr << " " << myInt;
   delete myPtr; // Deallocated from heap

   MyFct(); // Stack grows, then shrinks

   return 0;
}
```

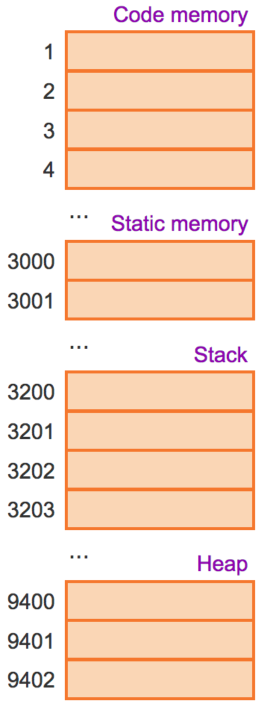


The code regions store program instructions. myGlobal is a global variable and is stored in the static memory region. Code and static regions last for the entire program execution.

Pointers

- Pointer: A variable that contains the address of another variable
- Declaration: *type ** pointer_name;

```
int* p;
```



Code memory

1

2

3

4

...

Static memory

3000

3001

...

Stack

3200

3201

3202

3203

...

Heap

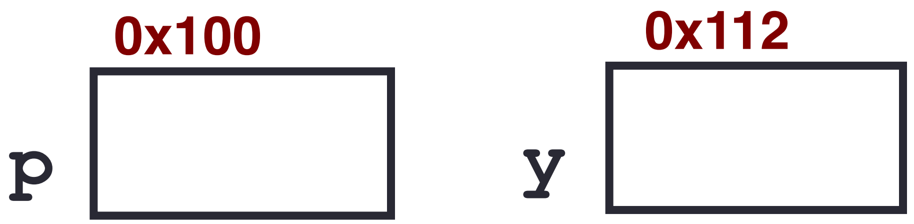
9400

9401

9402

How to make a pointer point to something

```
int* p;
int y = 3;
```



0x100

p

0x112

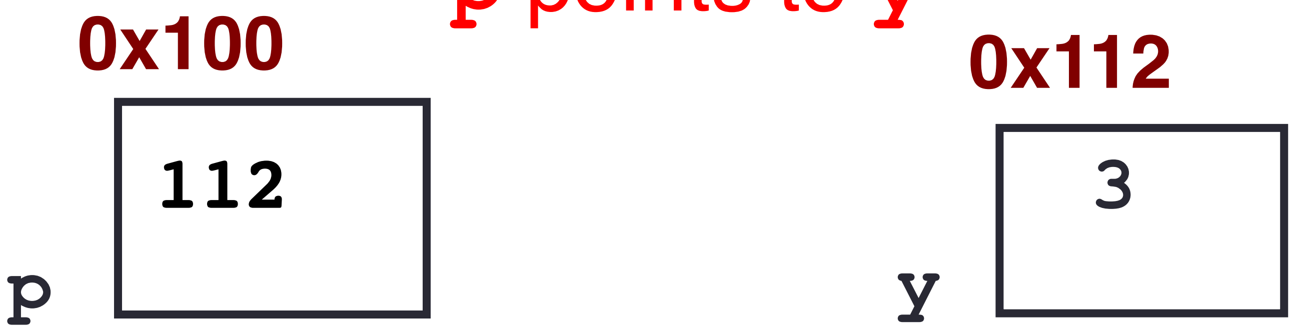
y

To access the location of a variable, use the address operator ‘&’

Pointer Diagrams:
Diagrams that show the relationship between pointers and pointees

`p` points to `y`

Pointer: p



0x100

`112`

`p`

0x112

`3`

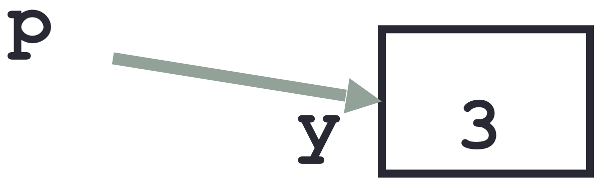
`y`

Pointee: y

You can change the value of a variable using a pointer !

```
int* p, y;
y = 3;
p = &y;

*p = 5;
```

Two ways of changing the value of a variable



- Change the value of y directly:

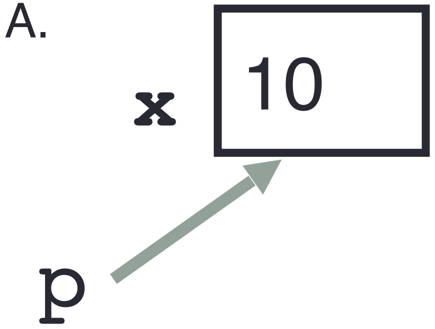
- Change the value of y indirectly (via pointer p):

Tracing code involving pointers

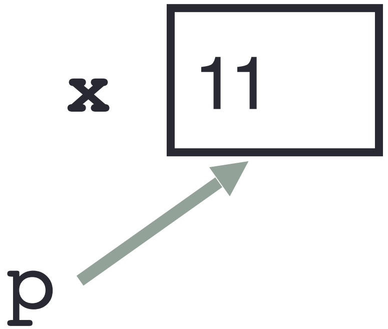
```
int* p;
int x = 10;
p = &x;
*p = *p + 1;
```

Q: Which of the following pointer diagrams best represents the outcome of the above code?

A.



B.



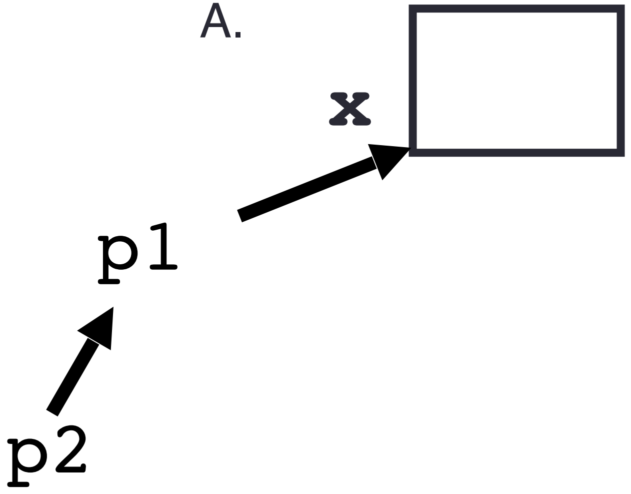
C. Neither, the code is incorrect

Pointer assignment

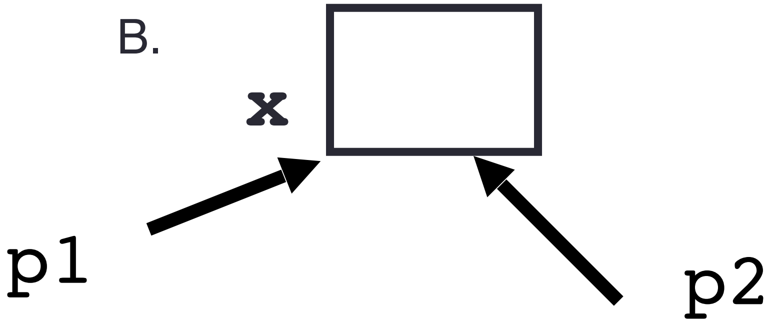
```
int* p1, *p2, x;
p1 = &x;
p2 = p1;
```

Q: Which of the following pointer diagrams best represents the outcome of the above code?

A.



B.



C. Neither, the code is incorrect

Arrays and pointers

	100	104	108	112	116
ar	20	30	50	80	90

- `ar` is like a pointer to the first element
- `ar[0]` is the same as `*ar`
- `ar[2]` is the same as `*(ar+2)`

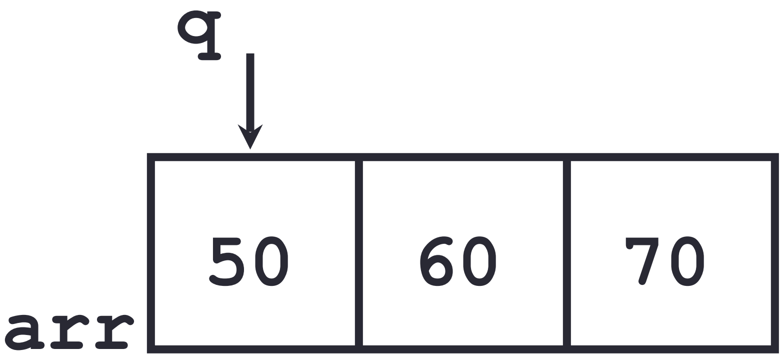
- Use pointers to pass arrays in functions
- Use *pointer arithmetic* to access arrays more conveniently

Pointer Arithmetic

```
int ar[]={20, 30, 50, 80, 90};
int* p;
p = arr;
p = p + 1;
*p = *p + 1;
```

Draw the array ar after the above code is executed

```
void IncrementPtr(int* p){
    p++;
}

int arr[3] = {50, 60, 70};
int* q = arr;
IncrementPtr(q);
```



Which of the following is true after **`IncrementPtr(q)`** is called in the above code:

A. **‘q’** points to the next element in the array with value 60

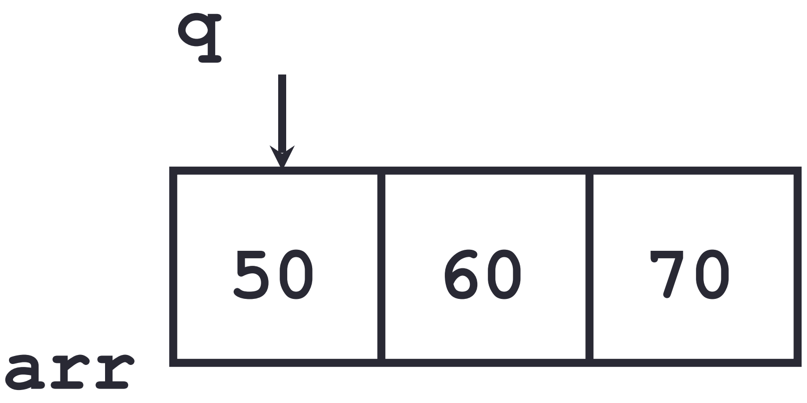
B. **‘q’** points to the first element in the array with value 50

How should we implement `IncrementPtr()`,so that ‘q’ points to 60 when the following code executes?

```
void IncrementPtr(int** p){
    p++;
}
```

```
int arr[3] = {50, 60, 70};
int* q = arr;
IncrementPtr(&q);
```

```
A. p =  p + 1;
B. &p = &p + 1;
C. *p= *p + 1;
D. p= &p+1;
```



Pointer pitfalls

- Dereferencing a pointer that does not point to anything results in undefined behavior.
- On most occasions your program will crash
- Segmentation faults: Program crashes because code tried to access memory location that either doesn’t exist or you don’t have access to

Two important facts about Pointers

1) A pointer can only point to one type –(basic or derived) such as `int`, `char`, a `struct`, another pointer, etc

2) After declaring a pointer: `int *ptr;`

   `ptr` doesn't actually point to anything yet.

   We can either:

   ➢ make it point to something that already exists, OR

   ➢ allocate room in memory for something new that it will point to

Pointer Arithmetic

- What if we have an array of large structs (objects)?
  - C++ takes care of it: In reality, `ptr+1` doesn’t add `1` to the memory address, but rather adds the size of the array element.
  - C++ knows the size of the thing a pointer points to – every addition or subtraction moves that many bytes: 1 byte for a char, 4 bytes for an int, etc.

References in C++

```
int main() {
  int d = 5;
  int &e = d;
}
```

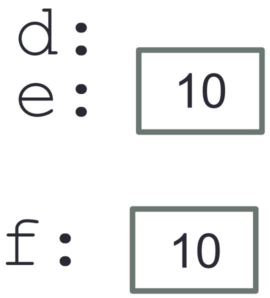
A reference in C++ is an alias for another variable

References in C++

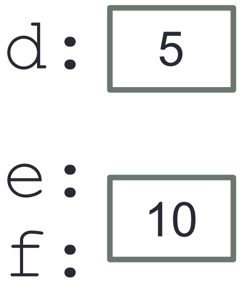
```
int main() {
   int d = 5;
   int &e = d;
   int f = 10;
   e = f;

}
```

How does the diagram change with this code?

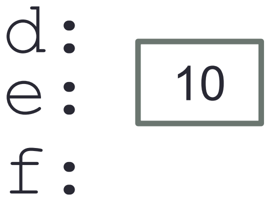
A.



B.

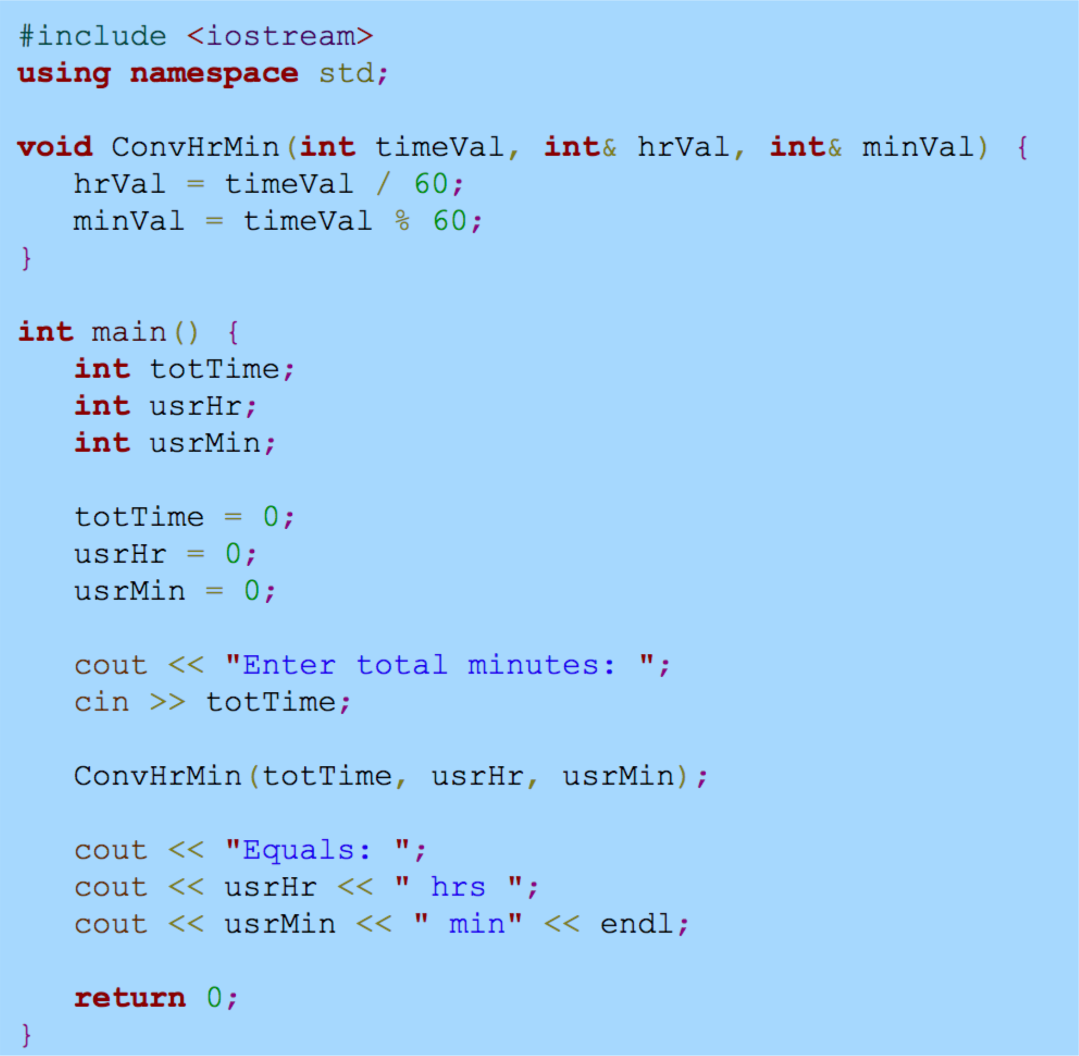


C.



D. Other or error

Passing arguments to functions by reference and by address



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

void ConvHrMin(int timeVal, int& hrVal, int& minVal) {
   hrVal = timeVal / 60;
   minVal = timeVal % 60;
}

int main() {
   int totTime;
   int usrHr;
   int usrMin;

   totTime = 0;
   usrHr = 0;
   usrMin = 0;

   cout << "Enter total minutes: ";
   cin >> totTime;

   ConvHrMin(totTime, usrHr, usrMin);

   cout << "Equals: ";
   cout << usrHr << " hrs ";
   cout << usrMin << " min" << endl;

   return 0;
}
```

Suppose the user enters a value of 125 for totTime
What is the output of the code?

Next time

- Dynamic Memory Management in C++