C++ MEMORY MODEL
DYNAMIC MEMORY
HEAP VS STACK

Problem Solving with Computers-I

C++

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

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

GitHub

Hi! Freq AC

Announcements

Please fill out the mid-quarter evaluations for:

(1) TAs: http://bit.ly/CS16-Midquarter-TA-Evaluation

(2) Course and instructor:
http://bit.ly/CS16-Midquarter-Instructor-and-Course-Evaluation

Link to both is posted on Piazza!

The case of the disappearing data!

```
int getInt(){
      int x=5;
      return x;
}
int* getAddressOfInt(){
      int x=10;
      return &x;
}
int main(){
      int y=0, *p=nullptr, z=0;
      y = getInt();
      p = getAddressOfInt();
      z = *p;
     cout<<y<<", "<<z<<", "<<*p<<endl;
}
```

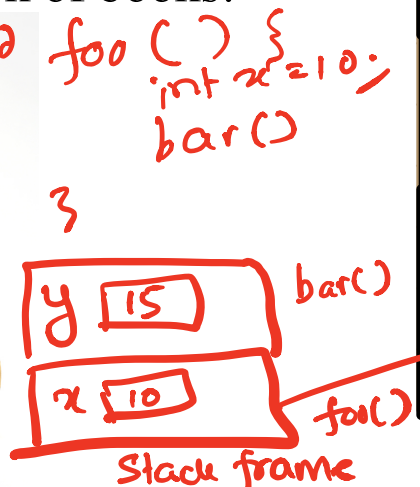
5 , 10 , 10

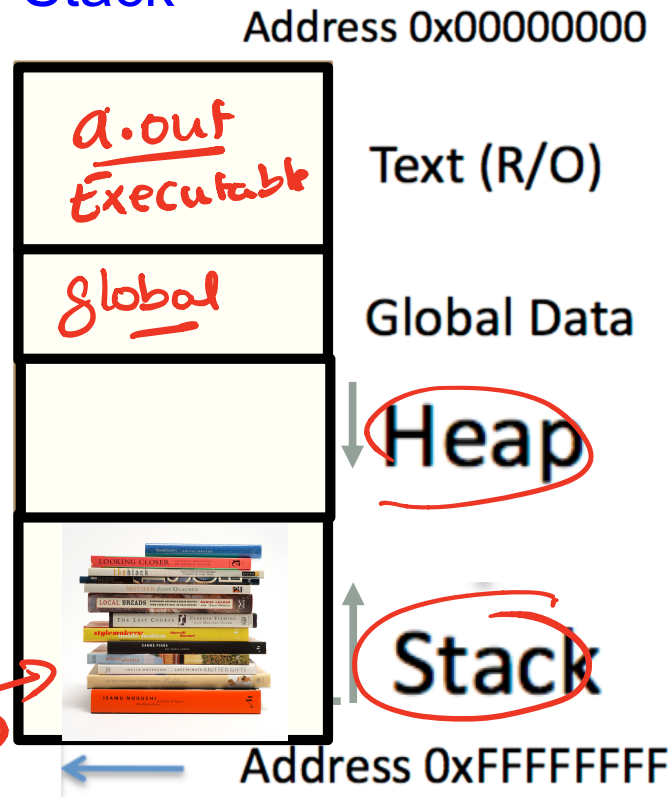
What is the output?

A. 5, 0, 10
B. 5, 10, 10
C. Something else

C++ Memory Model: Stack

- Stack: Segment of memory managed automatically using a Last in First Out (LIFO) principle
- Think of it like a stack of books!

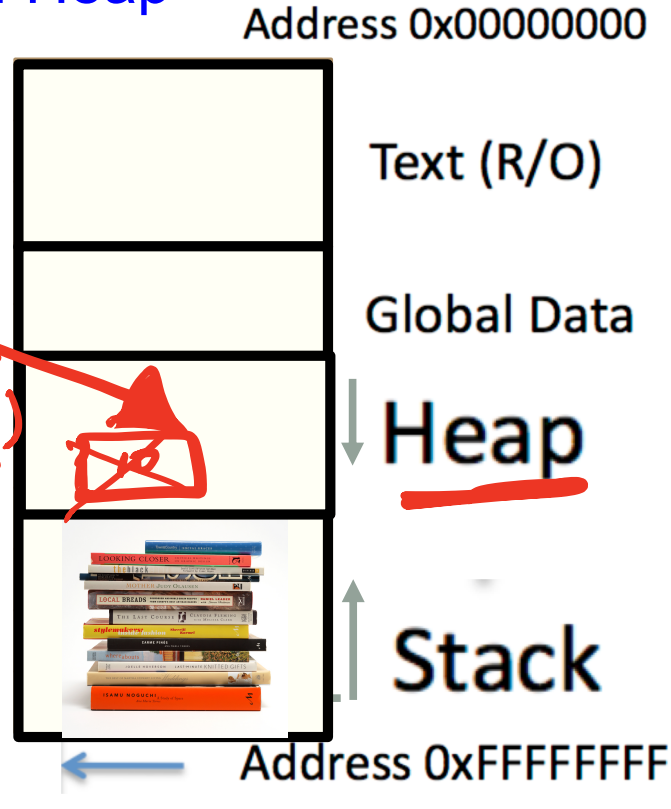




C++ Memory Model: Heap

- Heap: Segment of memory managed by the programmer
- Data created on the heap stays there
  - FOREVER or
  - until the programmer explicitly deletes it

Managed by the programmer (not automatically)



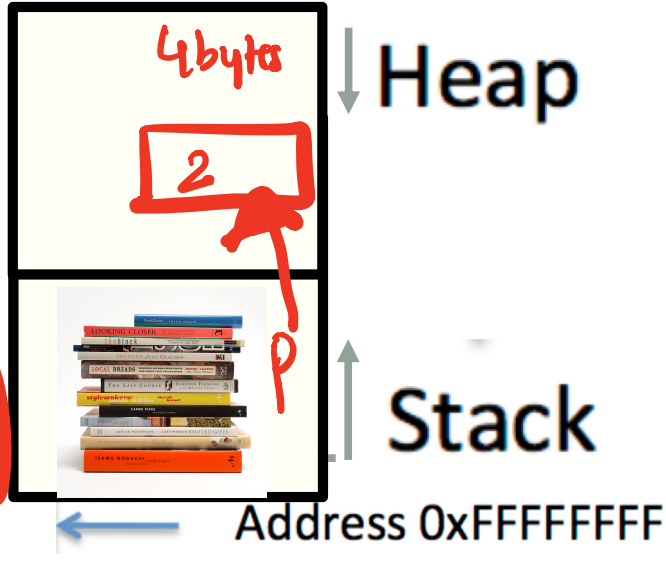
Creating data on the Heap: new

To **allocate** memory on the heap use the **new** operator

```
int x; // x is on the Stack
int* p;
p = new int;
*p = 2;
```

same as

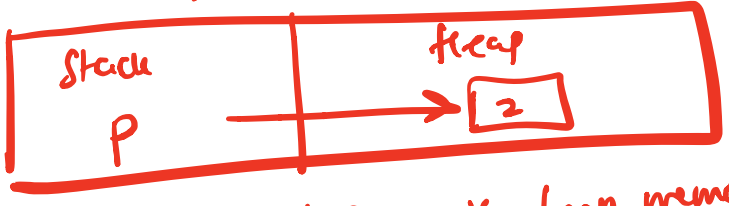
```
p = new int(2);
```



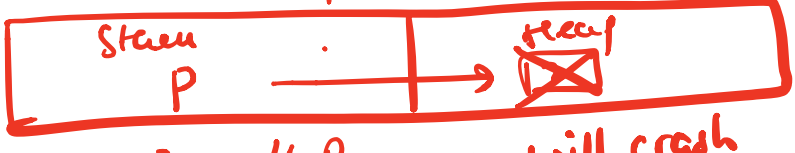
Deleting data on the Heap: delete

To **free** memory on the heap use the **delete** operator

```
int * p = new int(2);
```

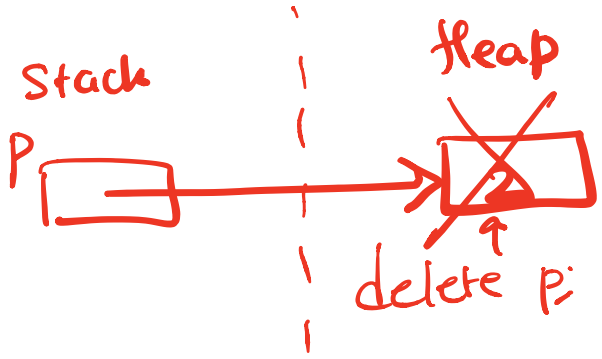



```
delete p; // frees the heap memory
          // p is still pointing to 2
```




```
*p = 5; // Program will crash
        // Cannot dereference p anymore
```

```
void foo() {
    int * p = new int(2);
    delete p;
}
```



Dynamic memory management = Managing data on the heap

```
int* p= new int; //creates a new integer on the heap

Student* n = new Student;
                    //creates a new Student on the heap

delete p; //Frees the integer

delete n; //Frees the Student
```

delete n; ← Crash! (double free error)

Solve the case of the disappearing data!

```
int getInt(){
      int x=5;
      return x;
}
int* getAddressOfInt(){
      int x=10;
      return &x;
}
int main(){
     int y=0, *p=nullptr, z=0;
     y = getInt();
     p = getAddressOfInt();
     z = *p;
     cout<<y<<", "<<z<<", "<<*p<<endl;
}
```

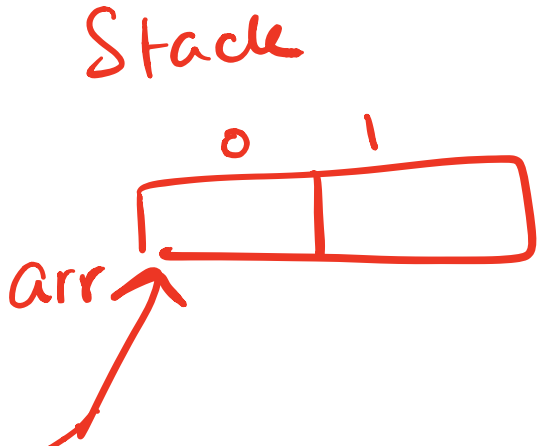
int * x = new int(10);
return x;

Change the code so that *p does not disappear

Desired output:
5, 10, 10

Heap vs. stack

```
1 #include <iostream>
2 using namespace std;
3
4 int* createAnIntArray(int len){
5
6     int arr[len];
7     return arr;
8
9 }
```



Does the above function correctly return an array of integers?

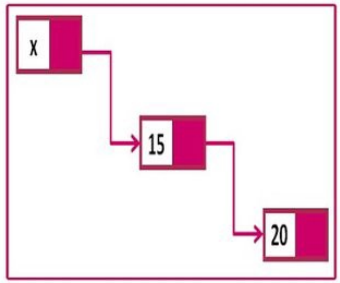
A. Yes

B. No

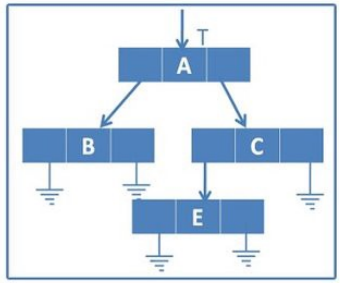
Array is on the stack & will be removed from the stack after the function returns

Where are we going? Data Structures!

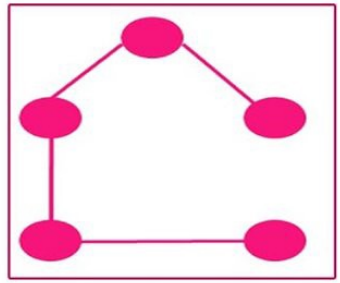
Arrays



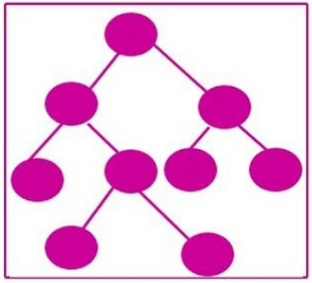
Link list



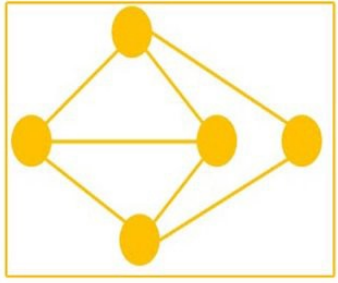
list



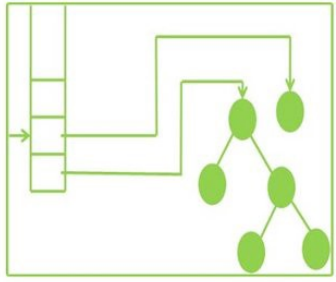
spanning tree



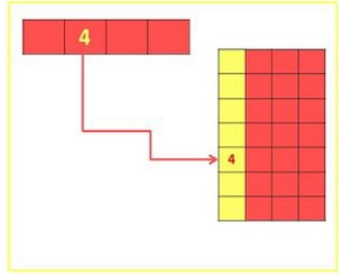
Tree



Graph



Stack

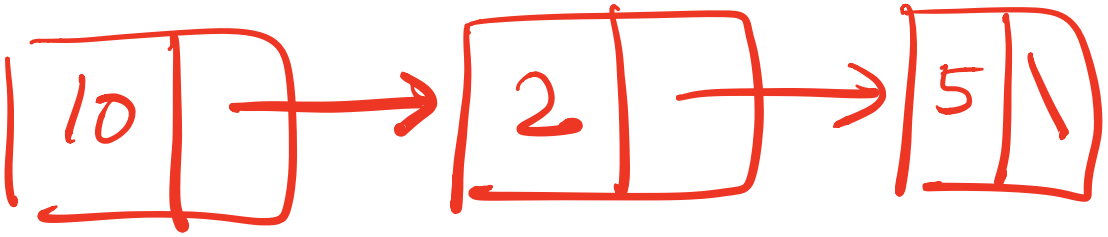


Hashing

array

int arr[3] = {10, 2, 5};

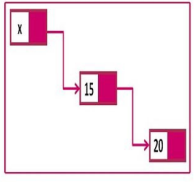
Linked list



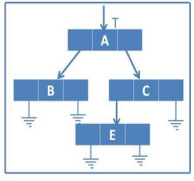
We can dynamically change the size of the chain.

Where are we going? Data structures!!

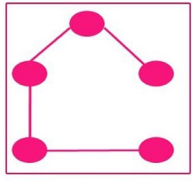
Arrays



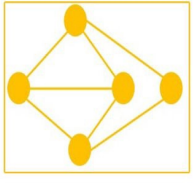
Link list



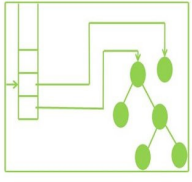
list



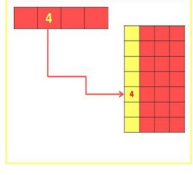
spanning tree



Graph



Stack

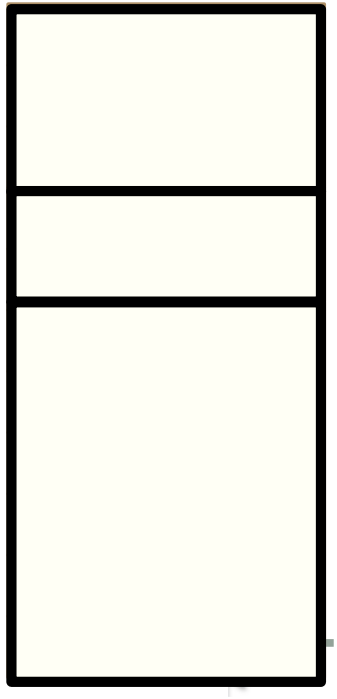


Hashing

By...navinkumardhoprephotography.com

(CS24/32)

It all boils down to 1's and 0's



Address 0x00000000

Text (R/O)

Global Data

Heap

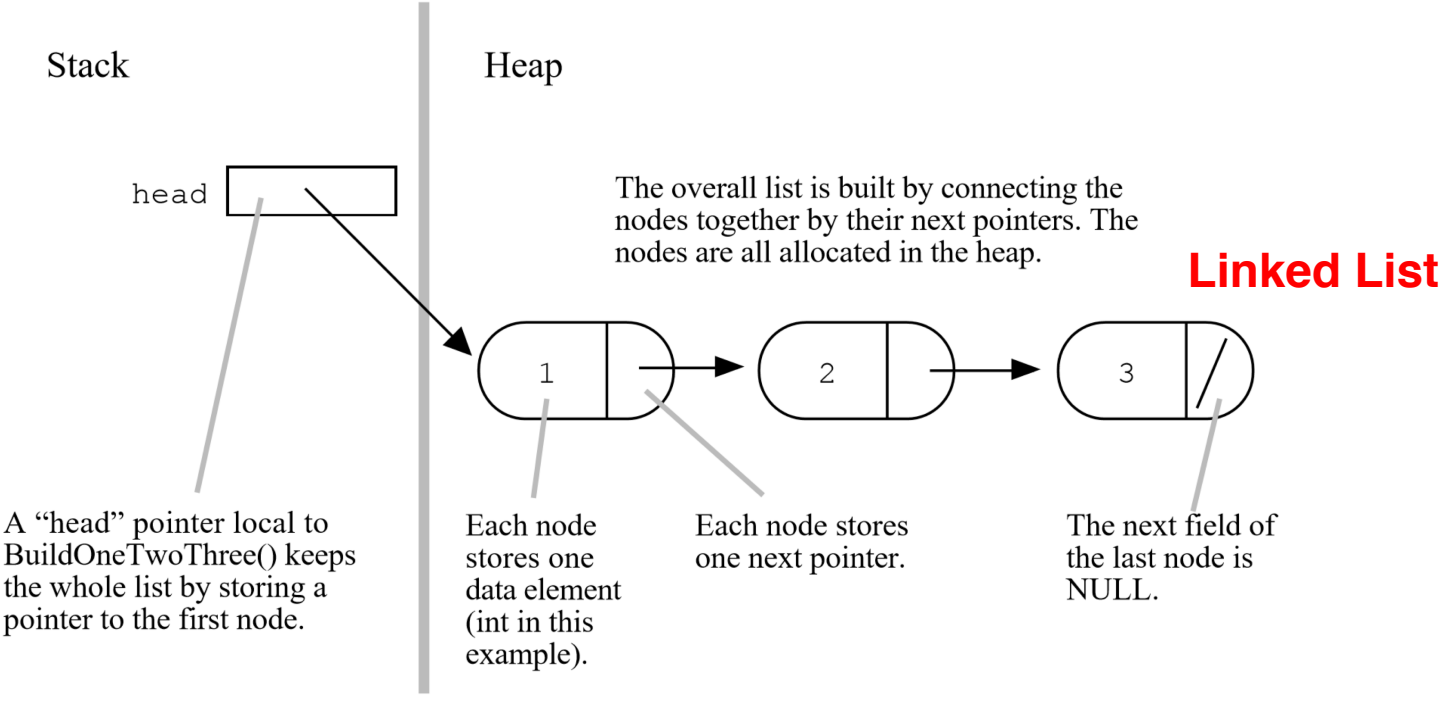
Stack

Address 0xFFFFFFFF

Linked Lists

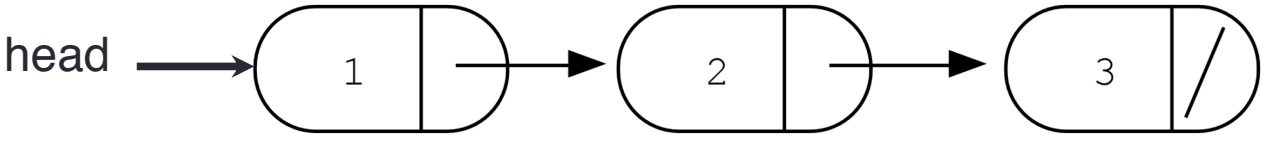
Array List

The Drawing Of List {1, 2, 3}



Accessing elements of a linked list

```
struct Node {
     int data;
     Node *next;
};
```



Assume the linked list has already been created, what do the following expressions evaluate to?

1. head->data
2. head->next->data
3. head->next->next->data
4. head->next->next->next->data

A. 1
B. 2
C. 3
D. NULL
E. Run time error

Create a small list – use only the stack

- Define an empty list
- Add a node to the list with data = 10

```
struct Node {
      int data;
      Node *next;
};
```

Heap vs. stack

```
Node* createSmallLinkedList(int x, int y){

    Node* head = NULL;
    Node n1 ={x, NULL};
    Node n2 ={y, NULL};
    head = &n1;
    n1->next = &n2;
    return head;
}
```

Does the above function correctly create a two-node linked list?

A. Yes
B. No

Pointer pitfalls and memory errors

- **Segmentation faults**: Program crashes because it attempted to access a memory location that either doesn't exist or doesn't have permission to access
- Examples of code that results in undefined behavior and potential segmentation fault

```
int arr[] = {50, 60, 70};

for(int i=0; i<=3; i++){
   cout<<arr[i]<<endl;
}
```

```
int x = 10;
int* p;
cout<<*p<<endl;
```

Dynamic memory pitfalls

Dangling pointer: Pointer points to a memory location that no longer exists

Which of the following functions returns a dangling pointer?

```
int* f1(int num){
    int* mem1 =new int[num];
    return(mem1);
}
```

```
int* f2(int num){
     int mem2[num];
     return(mem2);
}
```

A. f1
B. f2
C. Both
D. Neither

Dynamic memory pitfalls

Memory leaks (tardy free):

Heap memory not deallocated before the end of program

Heap memory that can no longer be accessed

Example

```
void foo(){
     int* p = new int;

}
```

Next time

- More Linked Lists