CS4414 Recitation 5

Pointers and Functions C++

09/24/2021

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Pointers

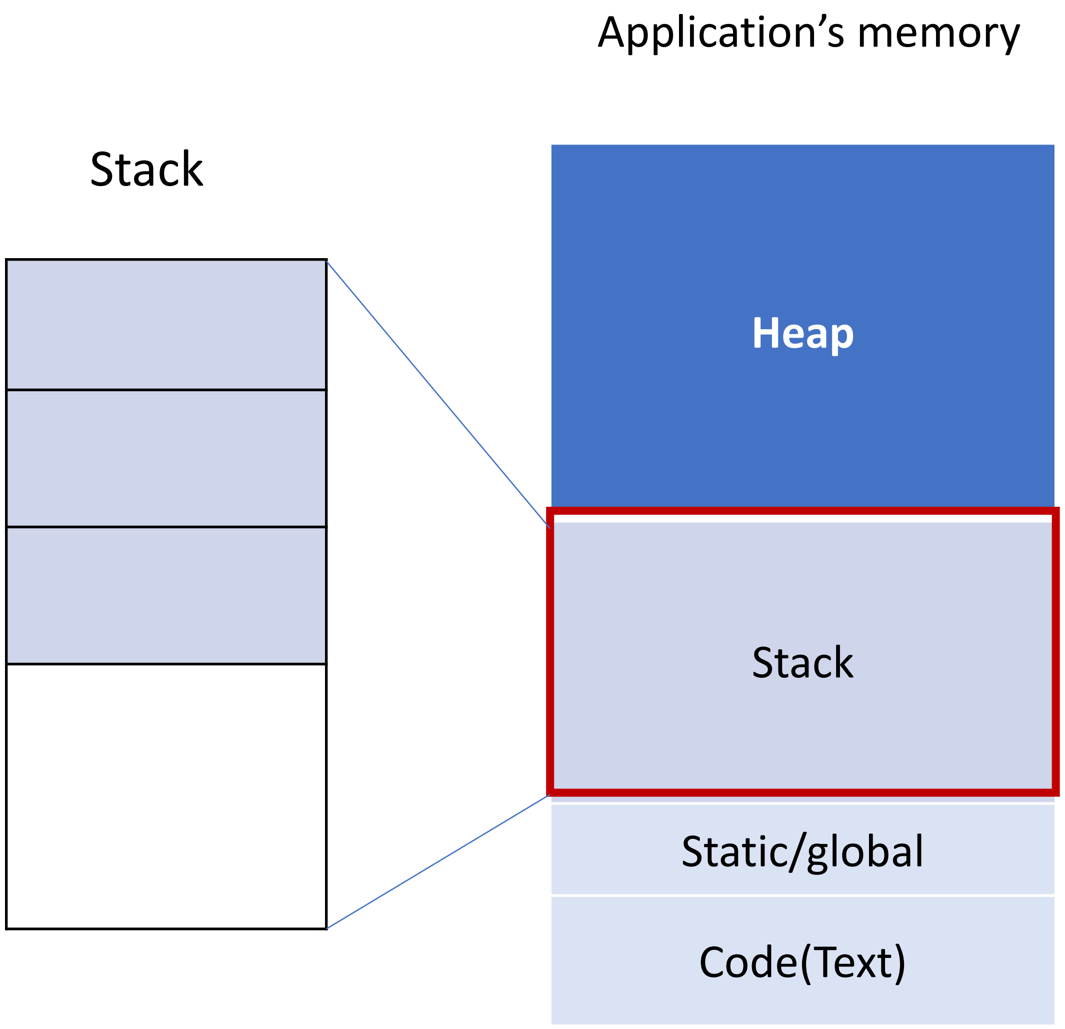
- Memory, Pointers and References
- Types of pointers
- ownership

Memory

--- stack and heap allocation

- Memory for C/C++/Java program: stack and heap

- Stack Allocation (Temporary memory allocation):
  - Allocate on contiguous blocks of memory, in a fixed size
  - Allocation happens in function call stack

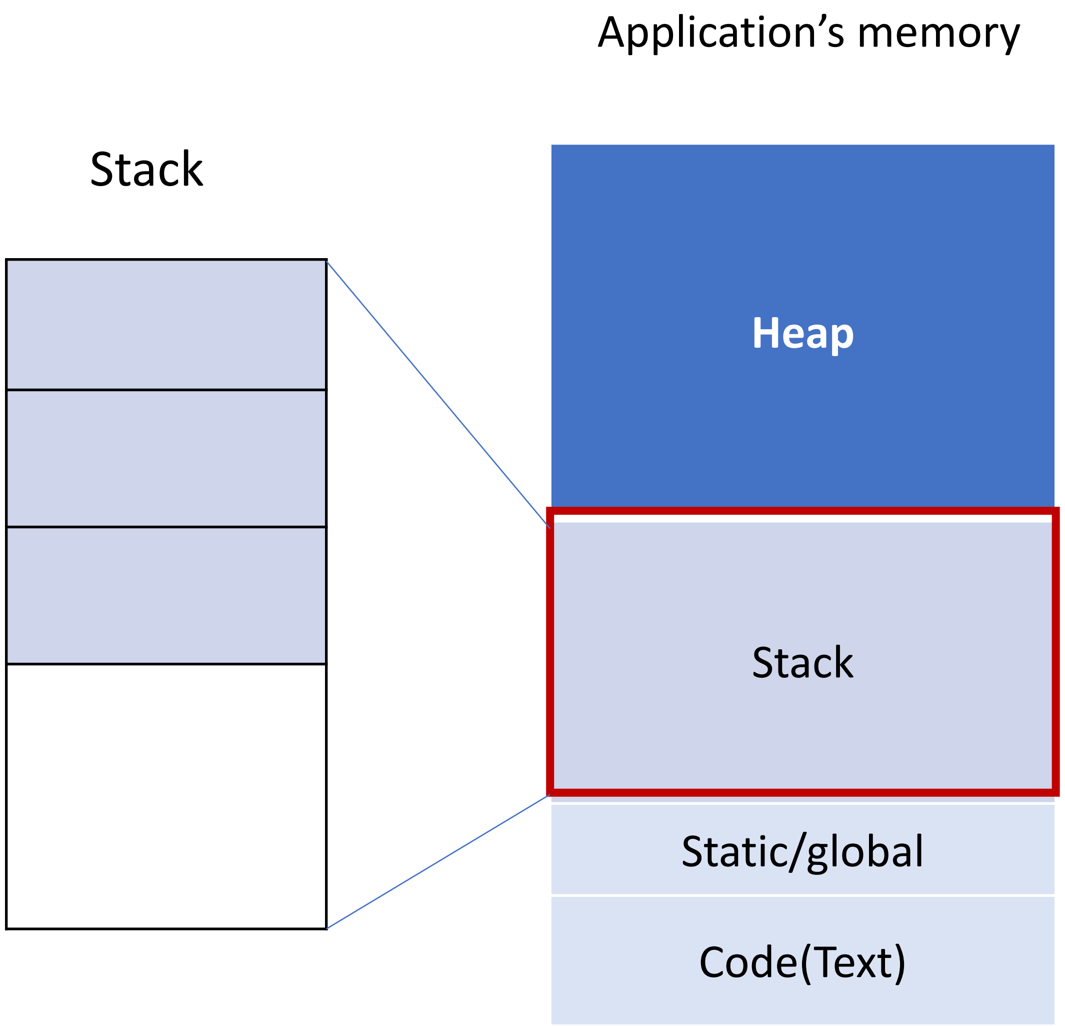


Memory

--- stack and heap allocation

- Memory for C/C++/Java program: stack and heap

- Stack Allocation (Temporary memory allocation):
  - Allocate on contiguous blocks of memory, in a fixed size
  - Allocation happens in function call stack
  - When a function called, its variables got allocated on stack; when the function call is over, the memory for the variables is deallocated. (scope)
  - Faster to allocate memory on stack(1CPU operation) than heap



Memory

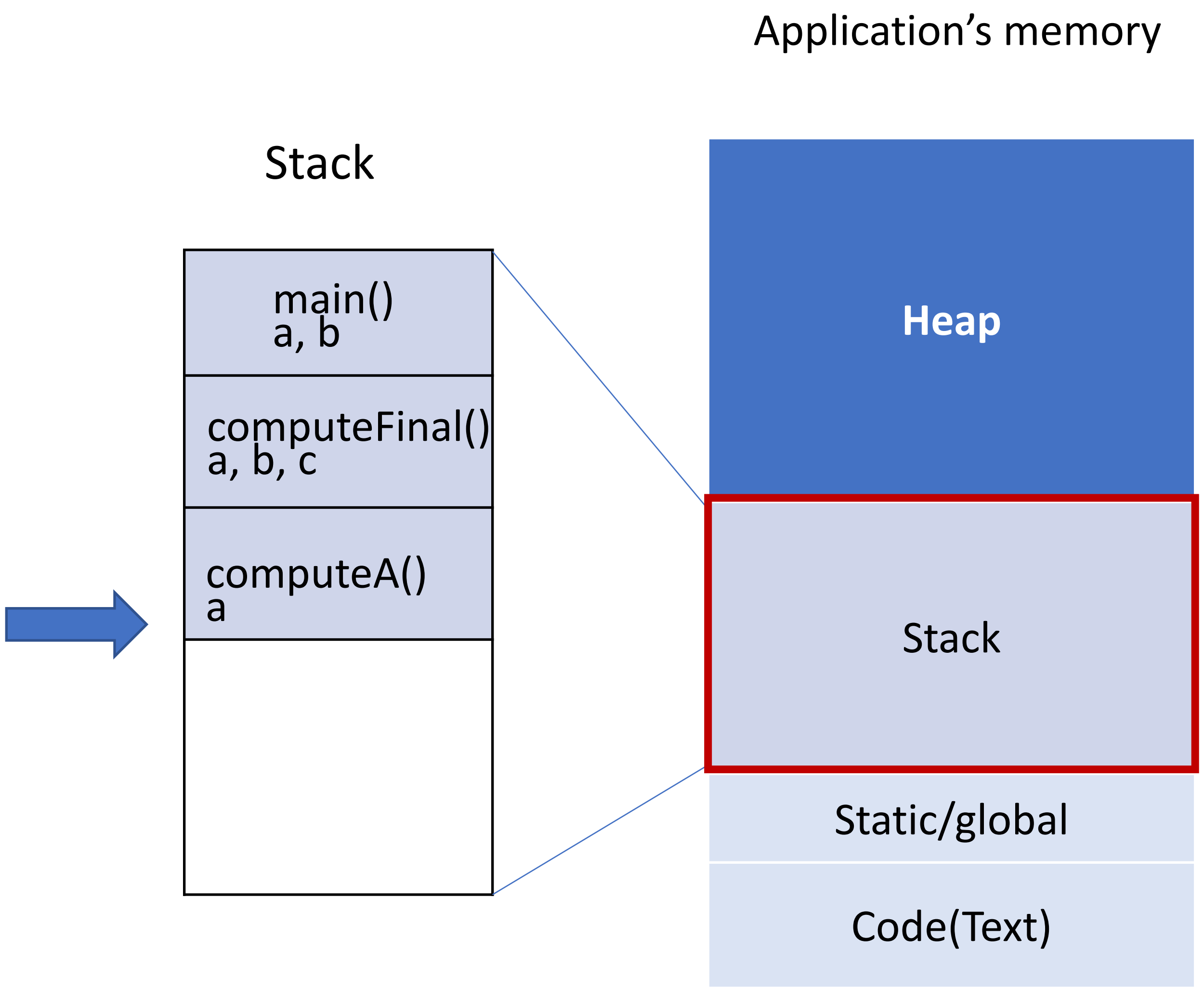
--- stack and heap allocation

- Stack Allocation (Temporary memory allocation):

```
int computeA(int a){ return a*a; }

int computeFinal(int a, int b){
    int c = computeA(a) + b;
    return c;
}

int main()
{
    int a = 1, int b = 2;
    total = computeFinal(a, b);
    return toal;
}
```



Memory

--- stack and heap allocation

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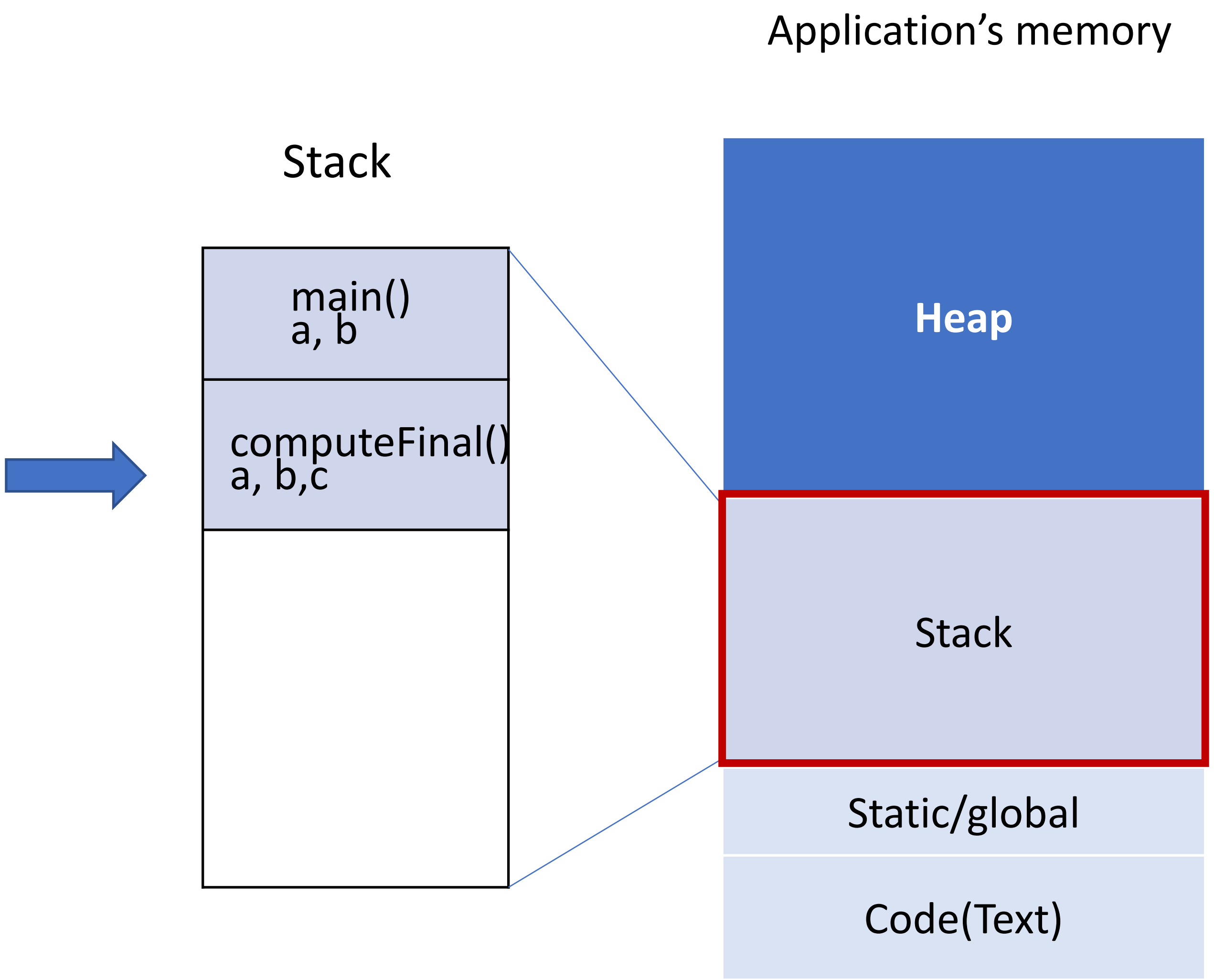

Memory

--- stack and heap allocation

- Stack Allocation (Temporary memory allocation):

Stack free memory via stack pointer

```
int computeA(int a){ return a*a; }

int computeFinal(int a, int b){
    int c = computeA(a) + b;
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}

int main()
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```
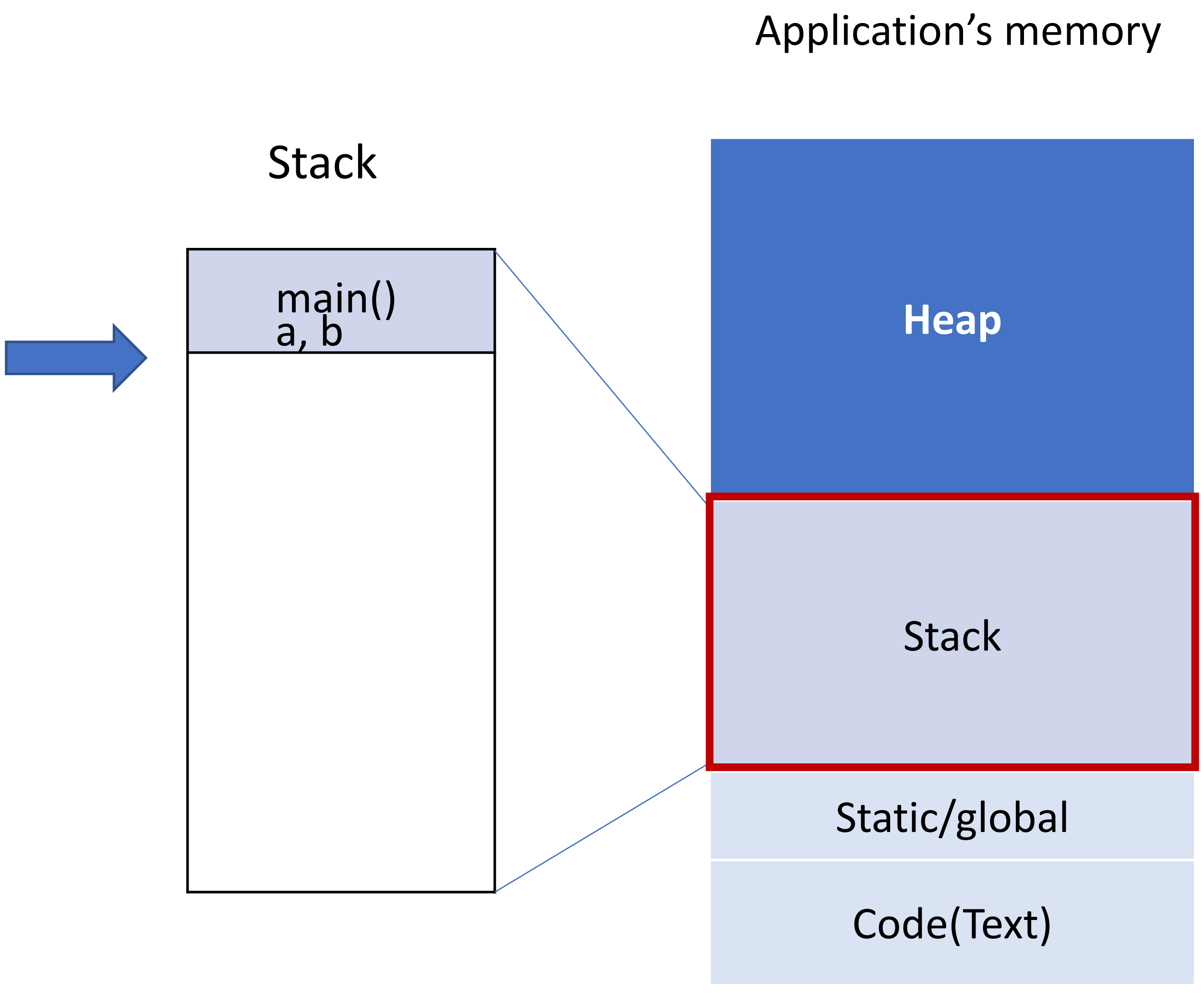
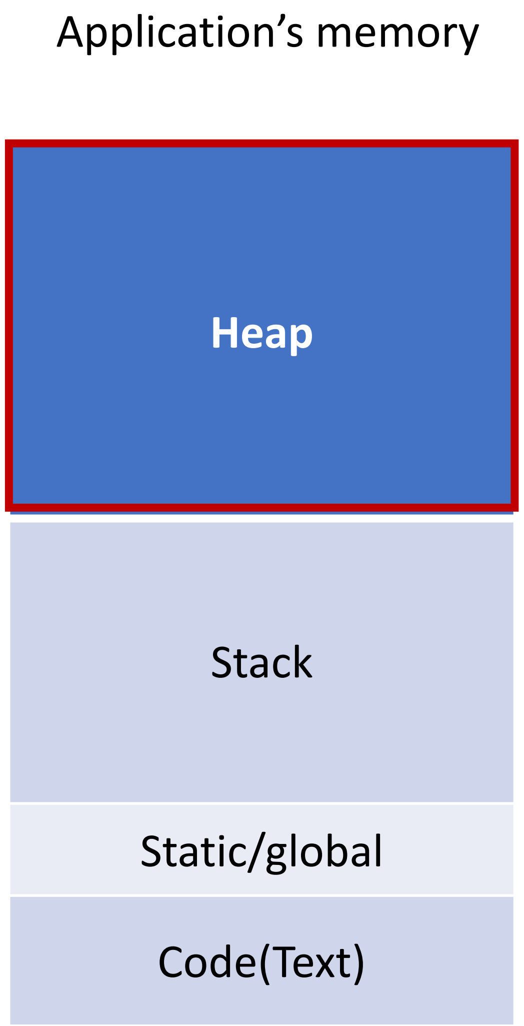



Memory

--- stack and heap allocation

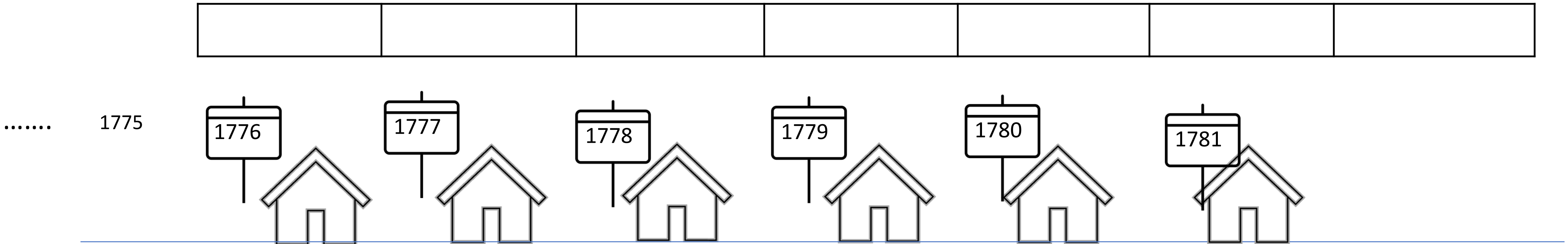
- Heap Allocation
  - Allocated during the execution of instructions written by programmers. (Variables allocated by heap could last longer than the span of the function)
  - no automatic de-allocation feature is provided. Need to use a Garbage collector to remove the old unused objects
  - Larger memory size compared to stack memory

```
int *ptr  = new int[10];          // This memory for 10 integers is
                                     allocated on heap
                                 //  new key word calls malloc()
```



Pointers

- A pointer is a variable that stores the memory address of an object.
- Why use pointers?
  - to allocate new objects on the heap
  - to pass functions to other functions
  - to iterate over elements in arrays or other data structures



Pointers

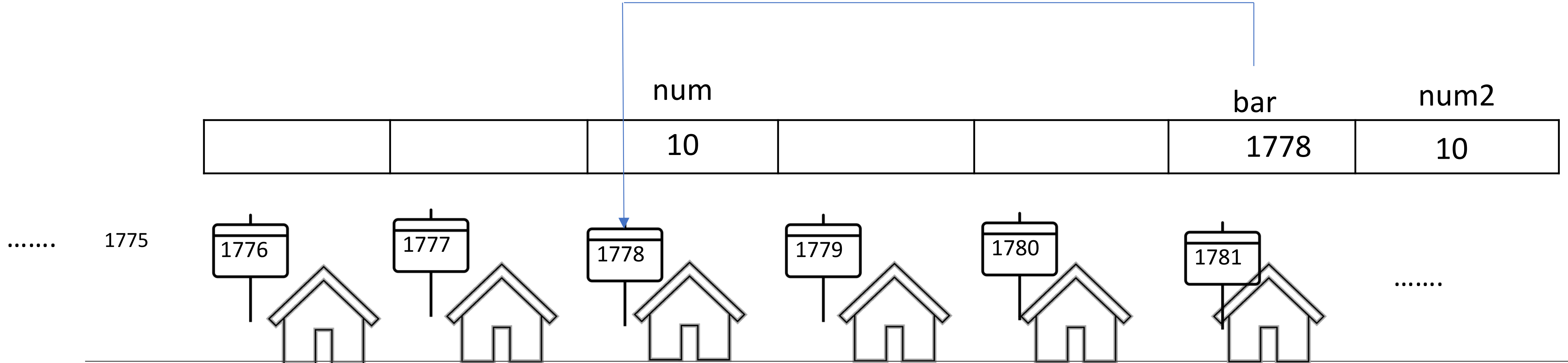
--- Address-of(&) and Dereference(*__) operators

- A pointer is a variable that stores the memory address of an object.
- Example:

```
int num = 10;

int* bar = &num;

int num2 = (* bar);
```

Hey, what **IS** your memory address?

Hey, what **IS stored IN** your memory address?



		num			bar	num2
		10			1778	10

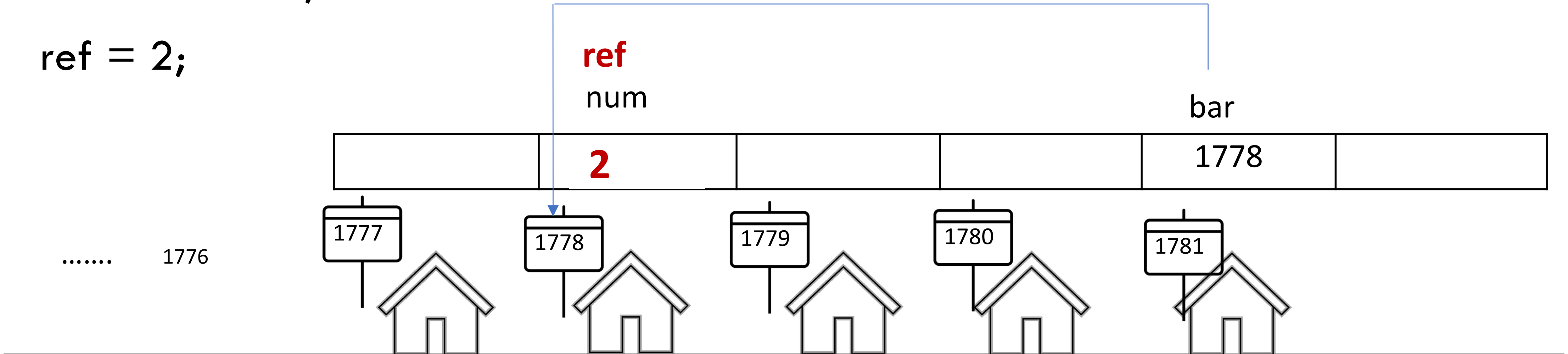
References

MAYBE IF I WEAR THIS SHIRT
NO ONE WILL BE ABLE TO TELL I'M SPIDERMAN

- Reference, is an alias, is another name for an already existing variable. It only exist in source code

```
int num = 10;
int* bar = &num;
int& ref = num;
ref = 2;
```

I'm a reference



Types of Pointers

- C-style raw pointers
- Smart pointers
  - unique_ptr : prefer, low overhead
  - shared_ptr
- Iterators

Types of Pointers

-- raw pointers

```
Example* example = new Example();
```

// Use the * operator to declare a pointer type
// Use new to allocate and initialize memory

```
Example example2 = *example;
```

// Copy the pointed-to object, by dereferencing the pointer
access the contents of the memory location.

```
Example* ecopy = &example2;
```

// Declare a pointer that points to example using the
address of operator

```
ecopy->print();
```

// Accessing filed/function of an object's pointer using ->

```
delete example;
```

// release memory back to OS, delete ecopy is dangerous
// anything allocate with new, should delete the memory to
prevent memory leak

Types of Pointers

- C-style raw pointers
- Smart pointers: wrapper of a raw pointer and make sure the object is deleted if it is no longer used
  - unique_ptr : prefer, low overhead
  - shared_ptr
- Iterators

Ownership of Pointers

- For C++ ownership is the responsibility for cleanup.
- The three types of pointers:
  - int * : does not represents ownership — can do anything you want with it, and you can happily use it in ways which lead to memory leaks or double-frees.
  - std::unique_ptr<int>: represents the simplest form of ownership (sole owner of resource and will get destroyed and cleaned up correctly)
  - std::shared_ptr<int> : one of a group of friends who are collectively responsible for the resource. The last of them to get destroyed will clean it up.

Types of Pointers

--- smart pointer: unique_ptr

- a smart pointer that owns and manages another object through a pointer and disposes of that object when the unique_ptr goes out of scope.

```
std::unique_ptr<Example> example = new Example();
```

✗

Unique_ptr needs to call the constructor explicitly

```
std::unique_ptr<Example> example(new Example());
```

✓

```
std::unique_ptr<Example> example = std::make_unique<Example>();
```

✓

```
std::unique_ptr<Example> example2 = example;
```

✗

unique_ptr class doesn’t allow copy of unique_ptr

```
std::unique_ptr<Example> example2 = std::move(example1);
```

✓

Demo: https://github.com/aliciayuting/CS4414Demo.git

Types of Pointers

--- smart pointer: shared_ptr

- Allow several shared_ptr objects own the same object.
- The object is destroyed and its memory deallocated, when the last shared_ptr owning the object is destroyed or is assigned to another pointer. (when Reference counting==0)

```
std::shared_ptr<Example> example = std::make_shared<Example>();
```

✓

```
std::shared_ptr<Example> example(new Example());
```

Less efficient, two allocations:
construct example, then construct control blo

```
std::shared_ptr<Example> example2 = example;
```

✓

Types of Pointers

- C-style raw pointers
- Smart pointers: wrapper of a raw pointer and make sure the object is deleted if it is no longer used
    - unique_ptr : prefer, low overhead
    - shared_ptr
- Array Pointer, Iterators

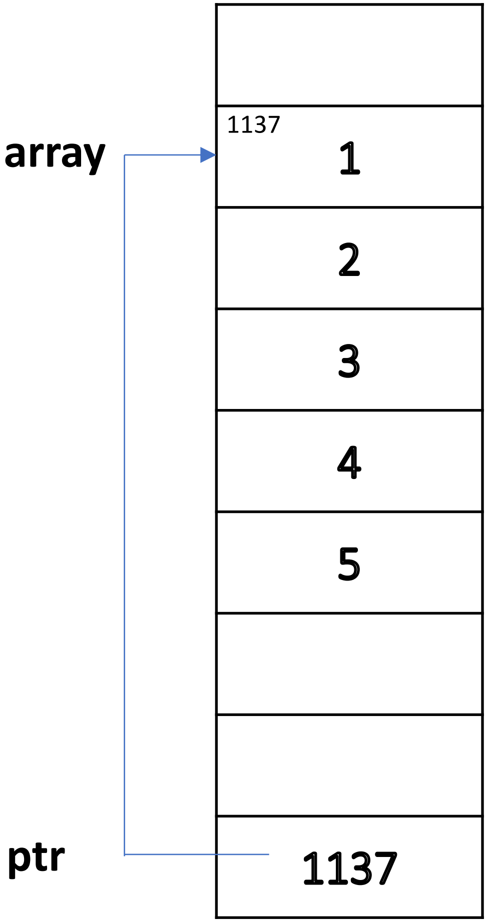
Types of Pointers

--- array pointer

- An array name is a pointer to the first element of the array
- *(array + ind) is equivalent to array[ind]

```
int array[5] = {1, 2, 3, 4, 5};
int* ptr;
ptr = array;
cout << *(array + 3) << endl;
cout << *(ptr + 3) << endl;
```

What are the print outs?



Types of Pointers

--- vector pointer

- **Vector pointer:** a direct pointer to the memory array by the vector to store its elements.
- Buggy code example:

```
std::vector<int> intVector;

intVector.push_back(1);

int* pointerToInt = &intVector[0];          // We get the pointer to the first element from our vector.
```

?

Types of Pointers

--- vector pointer

- **Vector pointer:** a direct pointer to the memory array by the vector to store its elements.
- Buggy code example:

```
std::vector<int> intVector;

intVector.push_back(1);

int* pointerToInt = &intVector[0];          // We get the pointer to the first element from our vector.

 intVector.push_back(2);
                                              // Add two more elements to trigger vector resize. During
 intVector.push_back(3);                      // resize the internal array is deleted causing our pointer
                                              // to point to an invalid location.

std::cout << "The value of our int is: " << *pointerToInt << std::endl;
```

?

Types of Pointers

--- vector pointer and iterator

- **Iterator:** An iterator is an object (like a pointer) that points to an element inside the container.
- **Container**: A container is a holder object that stores a collection of other objects (its elements). Like array, vector, dequeue, list …
- **Difference** between pointer and iterator:
  - An iterator may hold a pointer, but it may be something much more complex. (e.g. iterator can iterate over data that's on file system, spread across many machines.)
  - An iterator is more restricted, can only refer to object inside a container (e.g. vector, array) . A pointer of type T* can point to any type T object.

Types of Pointers

--- vector pointer and iterator

- vector<T>::iterator i: create an iterator for a vector of type T
- begin() : return the beginning position of the container
- end() : return the after end position of the container
- To access the elements in the sequence container by i++

```
std::vector<int> myvector;

For(int i=1; i<5 ; i ==) myvect.push_back(i) ;

for (std::vector<int>::iterator it = myvector.begin() ; it != myvector.end(); ++it)

   std::cout << ' ' << *it << std::endl;
```

Functions

Function Parameter

- Pass by value : passing the copy of the value

```
void fun(X x) { std::cout << x << std::endl; };          // declare a function
X x;                                                     // create a variable
fun(x);                                                  // call the function
```

- Pass by pointer : passing the copy of the value’s pointer

```
void fun(X *x);
X x;
fun(&x);                                           // & means get the address_of
```

- Pass by reference : passing a reference

```
void fun(X &x);                              // & means the parameter type is reference
X x;
fun(x);
```

Function Parameter

--- Passing vector

- When a vector value is passed to a function, a copy of the vector is created.

```
void func(vector<int> vect)
{
   vect.push_back(30);
}

int main()
{
    vector<int> vect;
    vect.push_back(10);
    vect.push_back(20);

    func(vect);
}
```

← Passing a vector value to a function:

- changes made inside the function are not reflected outside because function has a copy.

- it might also take a lot of time in cases of large vectors.

Function Parameter

--- Passing vector

- Pass by reference ✓

  (preferred to pass by reference than pass by pointer: **References cannot be null**.)

```
void func(vector<int>& vect)
{
   vect.push_back(30);
}

int main()
{
    vector<int> vect;
    vect.push_back(10);
    vect.push_back(20);

    func(vect);
}
```

Function Parameter

--- const

- Const keyword in parameter of **reference**: a promise that the variable being referenced to be changed through the reference.

```
void foo(const std::string& x) // x is a const reference
{
        x = "hello"; // compile error: a const reference cannot have its value changed!
}
```

Function Parameter

--- const

- Const keyword in parameter of **pointer**: declares the identifier as a pointer whose pointed at value is constant. This construct is used when pointer arguments to functions will not have their contents modified.

```
const type * identifier;

void fcn(const int* p){

        *p = expression;

}
```

// compiler complain: here it is illegal to have a const pointer's content change

Function Returns

- Return by value : returning a copy of the value

```
int value( int a ) {
        int b = a * a;
        return b;       // return a copy of b
}
```

- Return by reference

```
double& getValue( int i ) {
        return vals[i];       // return a reference to the ith element
}
```

Function Returns

- Return by value
- Return by reference
- Return a pointer :
  - Generally not a good idea to return a pointer to a local variable

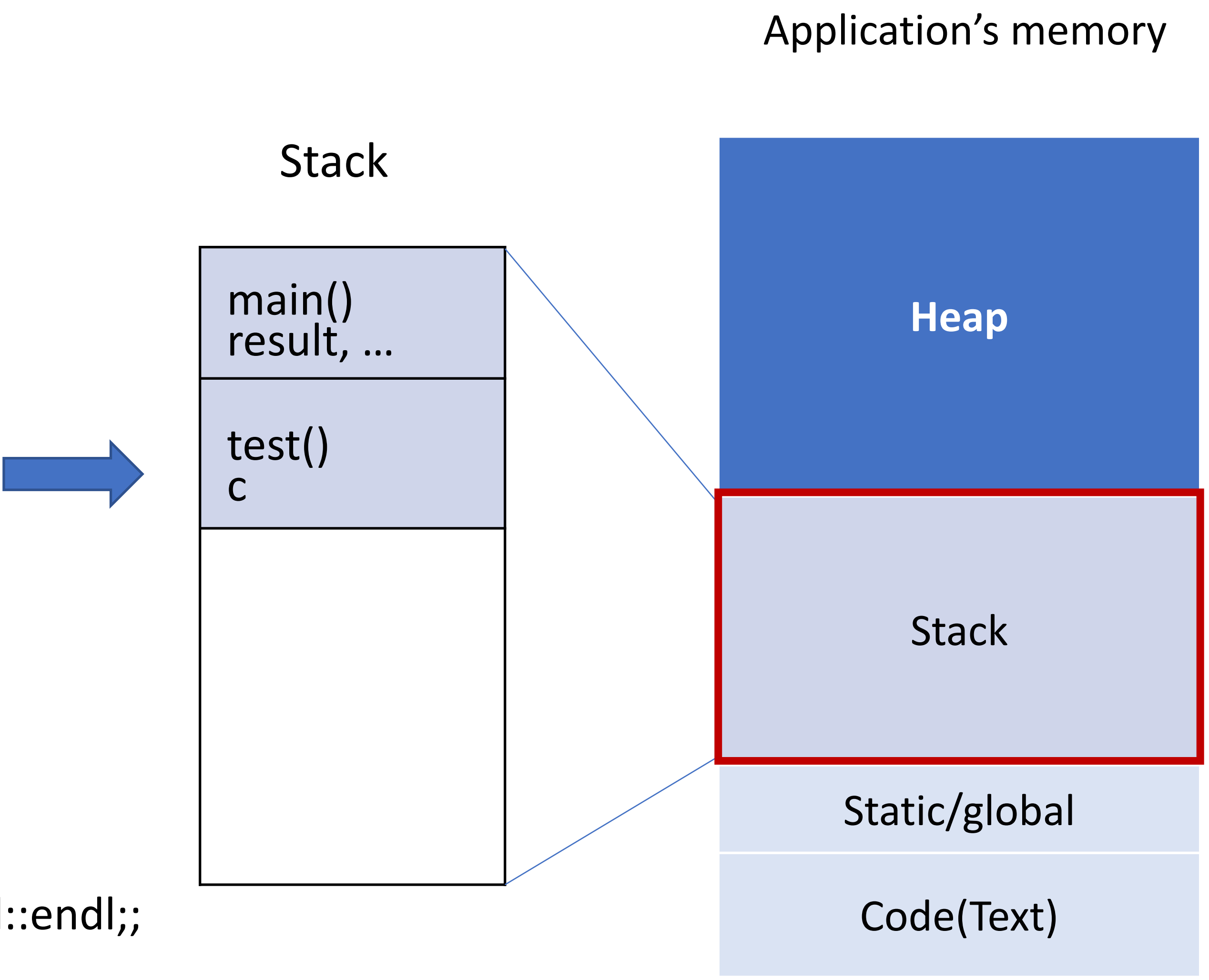
```
int* test () {
    int c[5];
    for (int i = 0; i < 5; i++)
        c[i] = i;
    return c;
}

int main(){
    int * result = test();
    std::cout << ”First Value is " << result[0] << std::endl;;
…
}
```

✗

Memory

- Why this code doesn’t work?

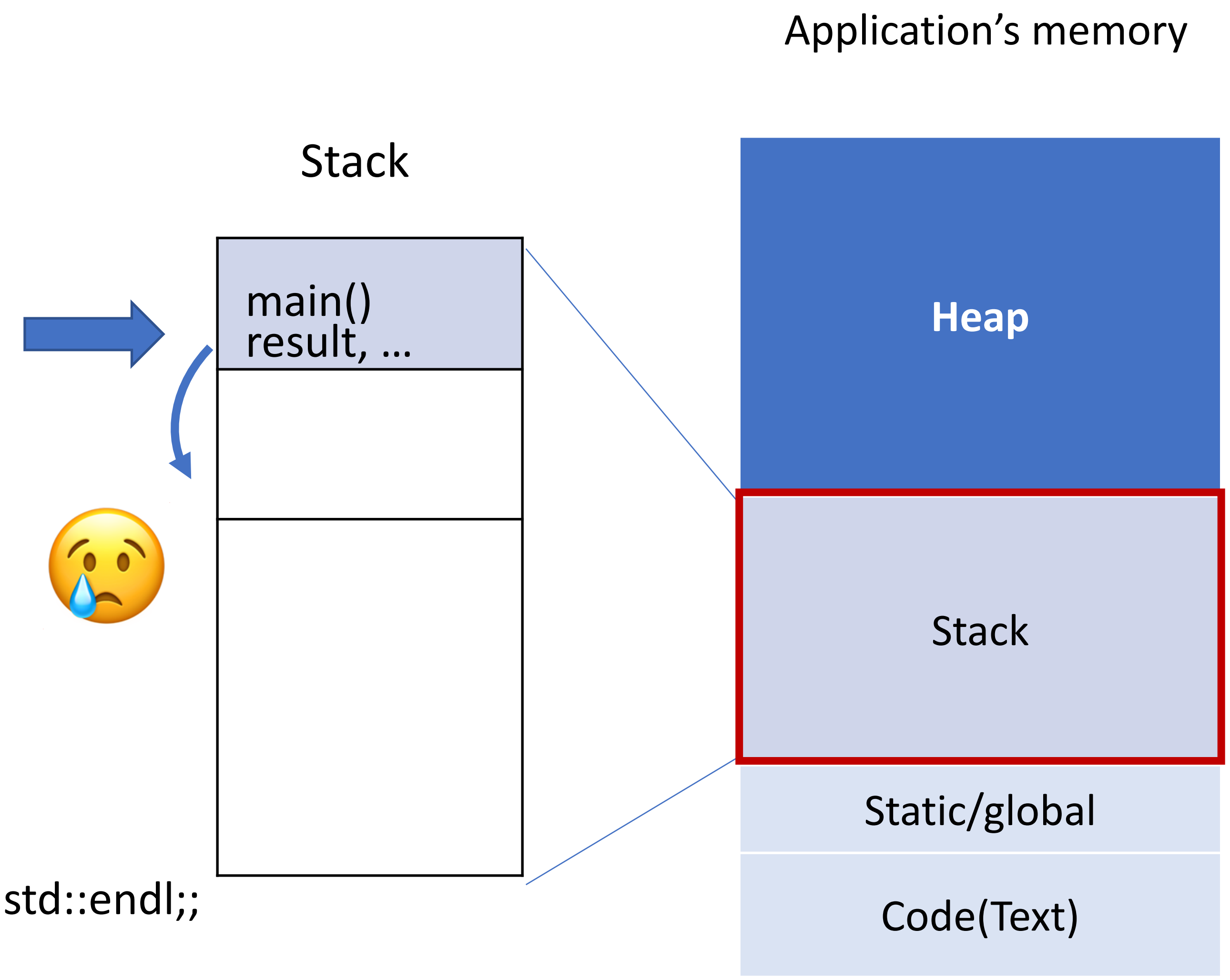
```
int* test () {
    int c[5];
    for (int i = 0; i < 5; i++)
        c[i] = i;
    return c;
}

int main(){
    int * result = test();
    std::cout << ”First Value is " << result[0] << std::endl;;
...
}
```



Memory

- Why this code doesn’t work?

```
int* test () {
    int c[5];
    for (int i = 0; i < 5; i++)
        c[i] = i;
    return c;
}

int main(){
    int * result = test();
    std::cout << ”First Value is " << result[0] << std::endl;;
...
}
```



Function Returns

--- array

- Return by value
- Return by reference
- Return a pointer
  - Generally not a good idea to return a pointer to a local variable

Fix1. std::array (better)

```
std::array<int,5> test () {
  std::array<int,5> c;
  for (int i = 0; i < 5; i++)
        c[i] = i;
  return c;
}
```

Fix2. use heap

```
int* test (void) {

    int* out = new int[5];

    return out;

}
```

(need to release the memory of the returned pointer)

Demo: https://github.com/aliciayuting/CS4414Demo.git

Function Returns

--- vector

- Example:

Does this program work as intended?

```
class Student{
private:
            std::string name;
public:
            Student(const std::string& name) :
                                                name(name){}
            std::string get_name() {
                        return name;
            }
};
```

```
class CS4414{
private:
            std::vector<Student> students;
public:
            std::vector<Student> get_students(){
                        return students;
            }
};
```

Demo: https://github.com/aliciayuting/CS4414Demo.git

Where to find the resources?

- Memory Heap and Stack: https://www.geeksforgeeks.org/stack-vs-heap-memory-allocation/
- Pointers: https://docs.microsoft.com/en-us/cpp/cpp/pointers-cpp?view=msvc-160 , https://www.cplusplus.com/doc/tutorial/pointers/
- Move semantics: https://www.cprogramming.com/c++11/rvalue-references-and-move-semantics-in-c++11.html
- Iterators: https://www.geeksforgeeks.org/introduction-iterators-c/
- difference between pointers: https://www.geeksforgeeks.org/difference-between-iterators-and-pointers-in-c-c-with-examples/
- Passing arguments by reference: https://www.learncpp.com/cpp-tutorial/passing-arguments-by-reference/