Computer Programming

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Session: Pointers and Dynamic Memory – Part 1

Quick Recap of Relevant Topics

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- Variables and pointers to variables in C++
- Storage in stack segment
- “Address of” operator: &
- “Content of” operator: *

Memory locations accessed: local variables/arrays of functions

Statically allocated in stack segment when function is called

Overview of This Lecture

- Storage in data segment (heap)
- Dynamic allocation of memory in C++
- Accessing dynamically allocated memory
- Good programming practices when using dynamic memory

Memory For Executing A Program (Process)

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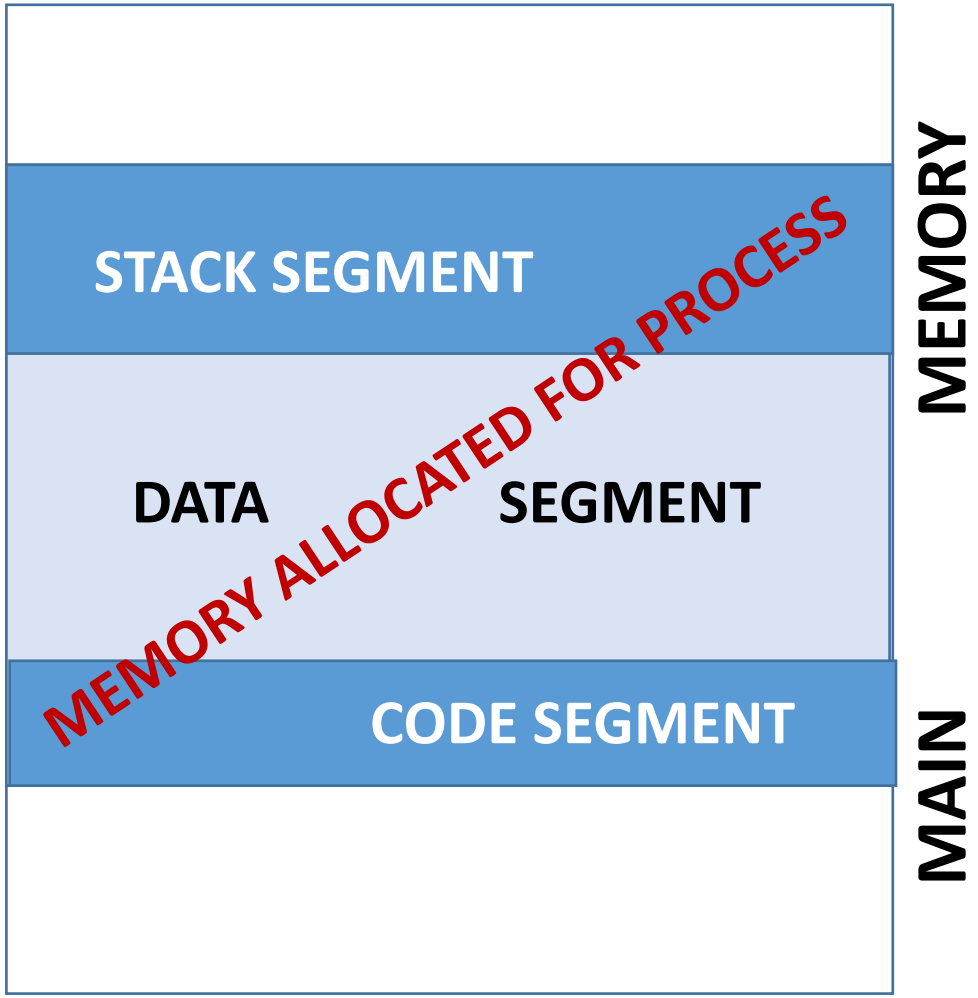
- Operating system allocates a part of main memory for use by a process
- Divided into:

  Code segment: Stores executable instructions in program

  Data segment: For dynamically allocated data (this lecture)

  Stack segment: Call stack



Memory For Executing A Program (Process)

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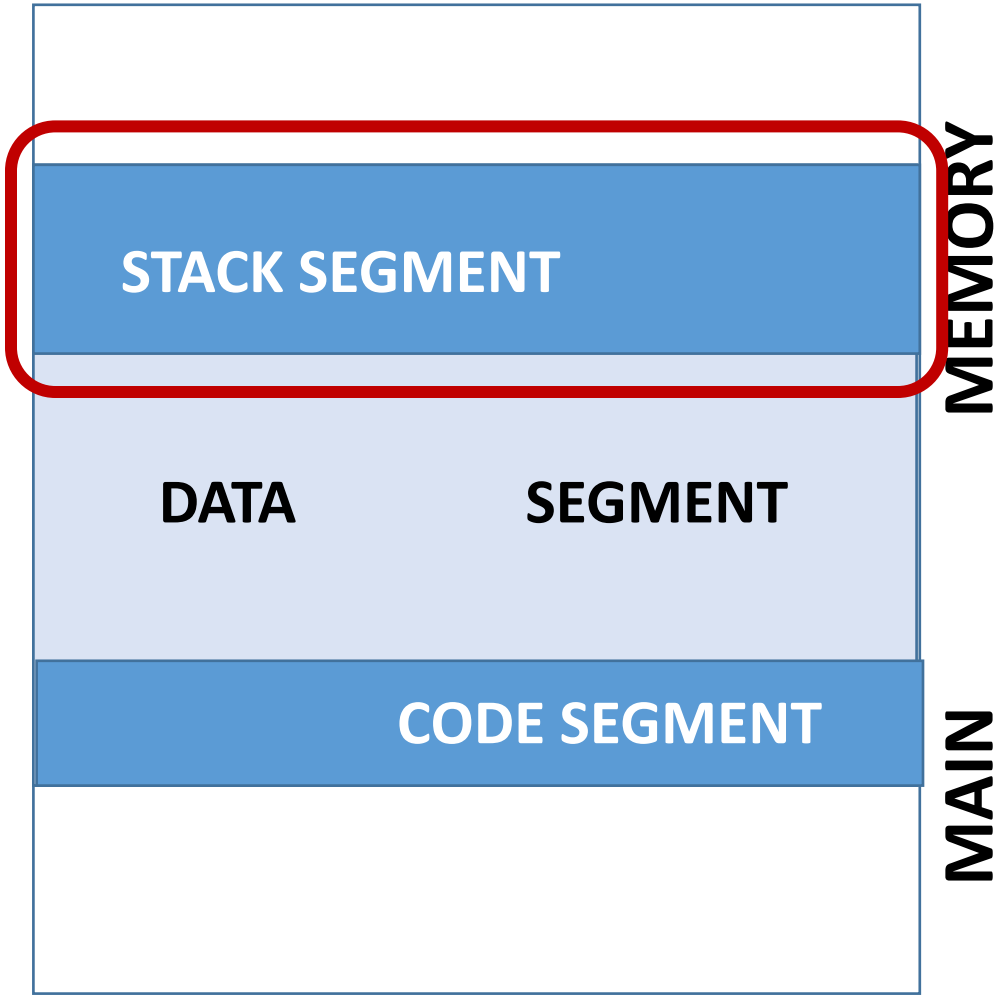
Local variables/arrays of a function

- Must be statically declared in function
- Memory allocated in activation record of function
- Resides in stack segment
- Ceases to exist once function ends and control returns to caller



Memory For Executing A Program (Process)

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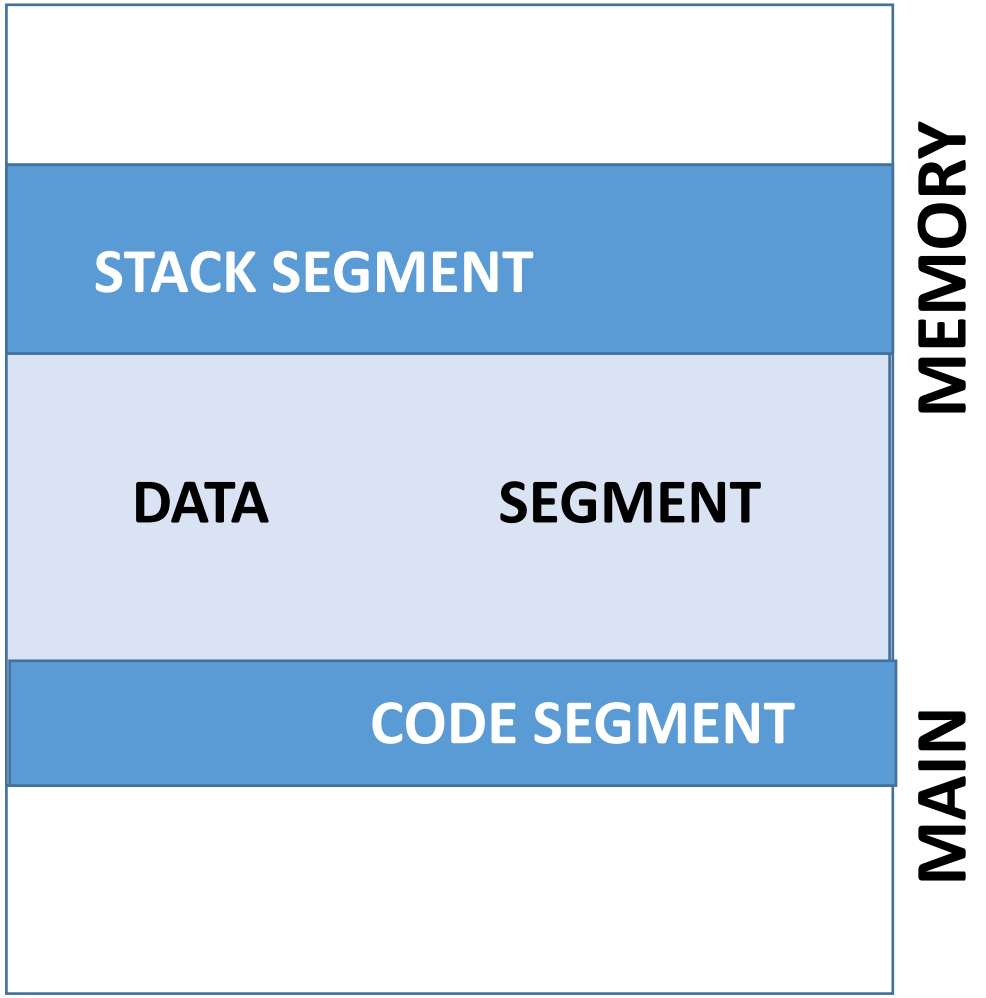
What if the size of a local array is input-dependent?

Examples:

Read number of students in a class and store marks of all students in an int array.

Read a sequence of characters ending with "." and store in a char array



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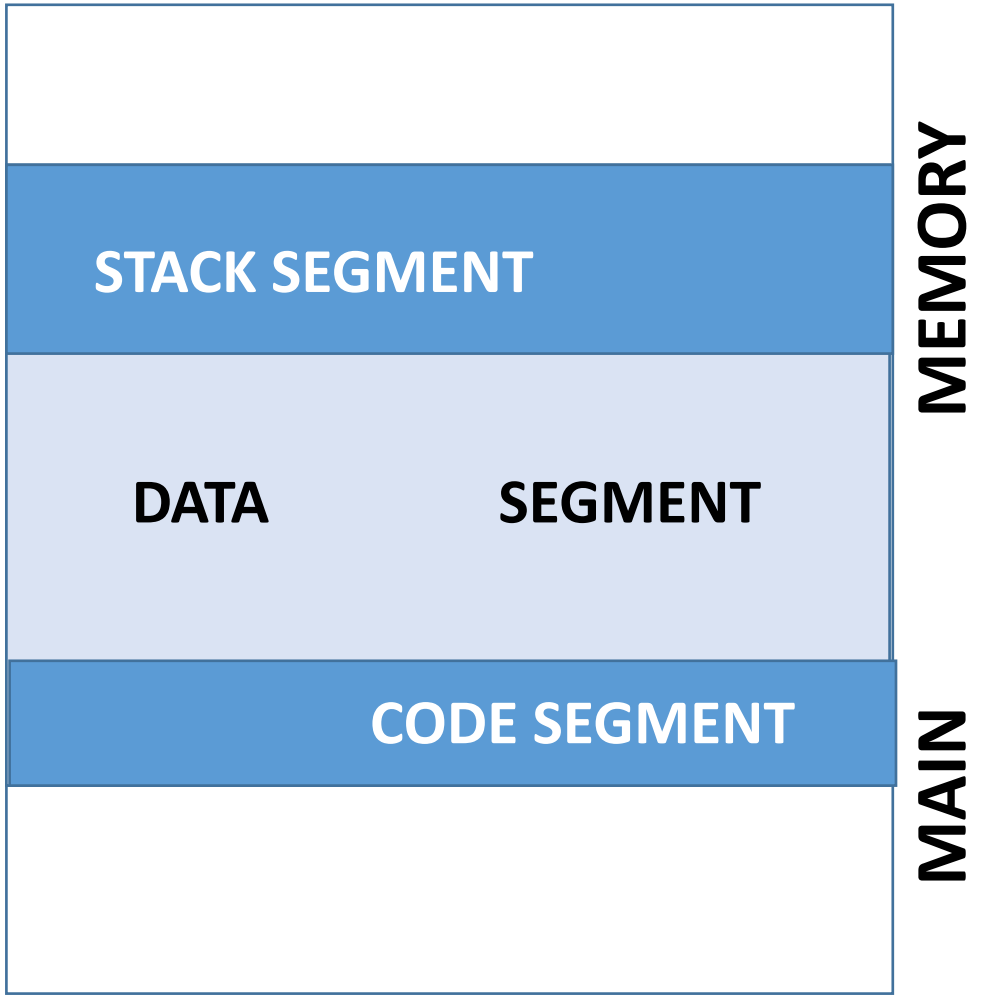
What if memory location(s) allocated in a function must be accessed after the function returns?

Examples: A function to read and store a sequence of characters in a char array, which must be used by the calling function



Memory For Executing A Program (Process)

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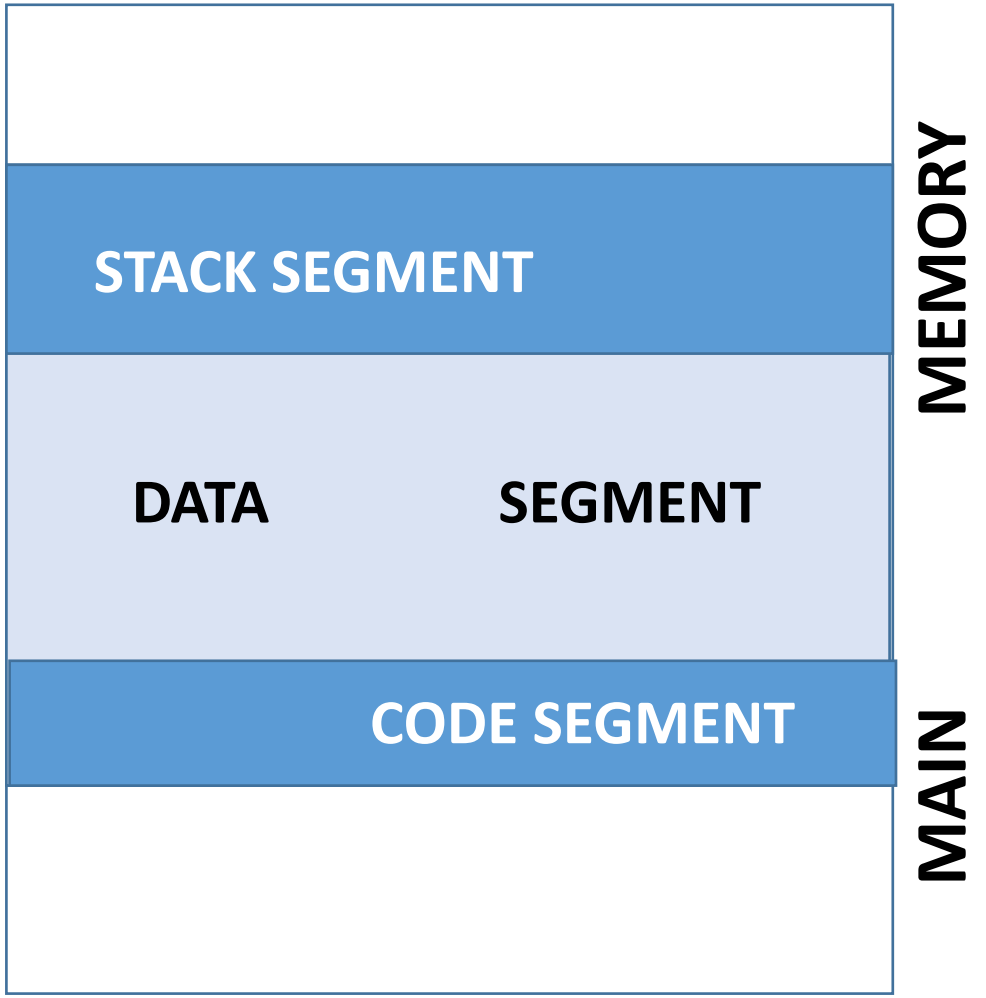
We need a mechanism for allocating memory locations **dynamically**

Dynamic memory allocation: Allocation at run time

Allocation could depend on values of expressions read/computed

[number of students, number of chars in name…]



Memory For Executing A Program (Process)

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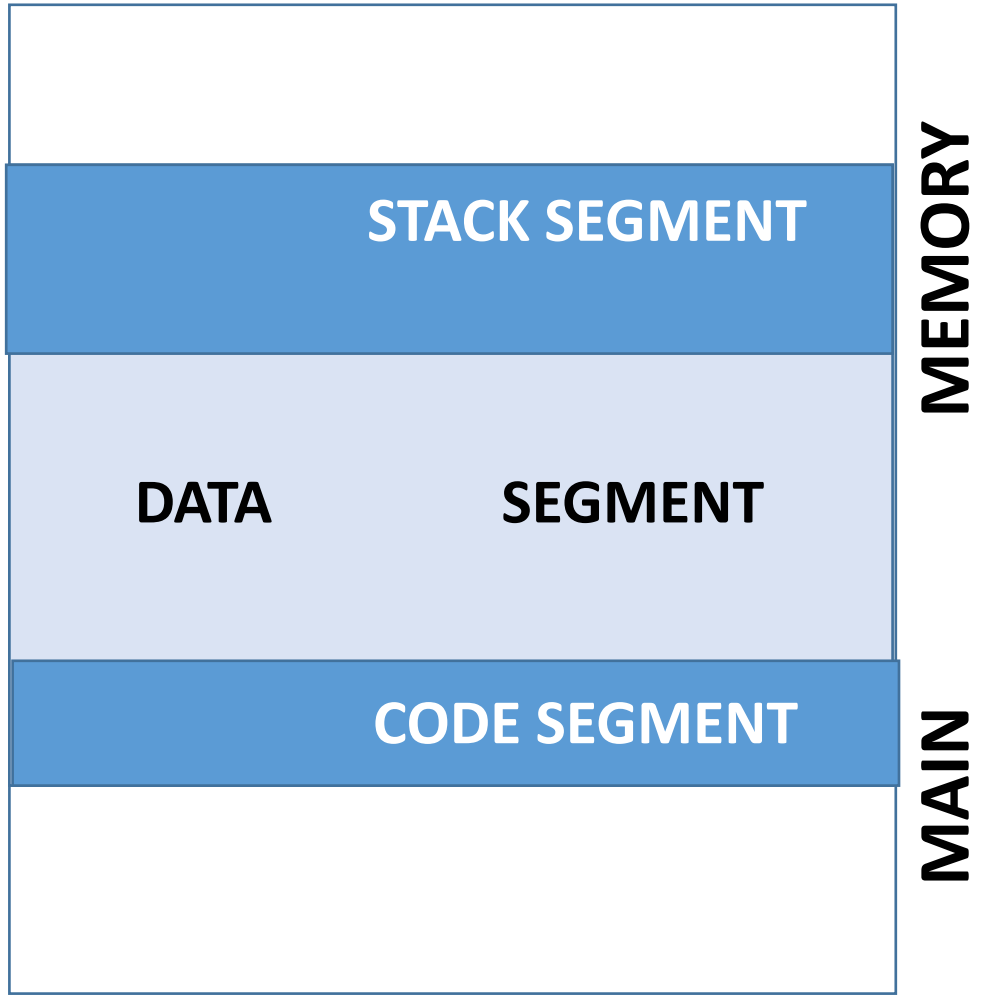
```
int main()
{
   int numStudents;
   cin >> numStudents;
  // Allocate an int array A
  // of size  numStudents
  // Store quiz marks in A
 return 0;
}
```



Memory For Executing A Program (Process)

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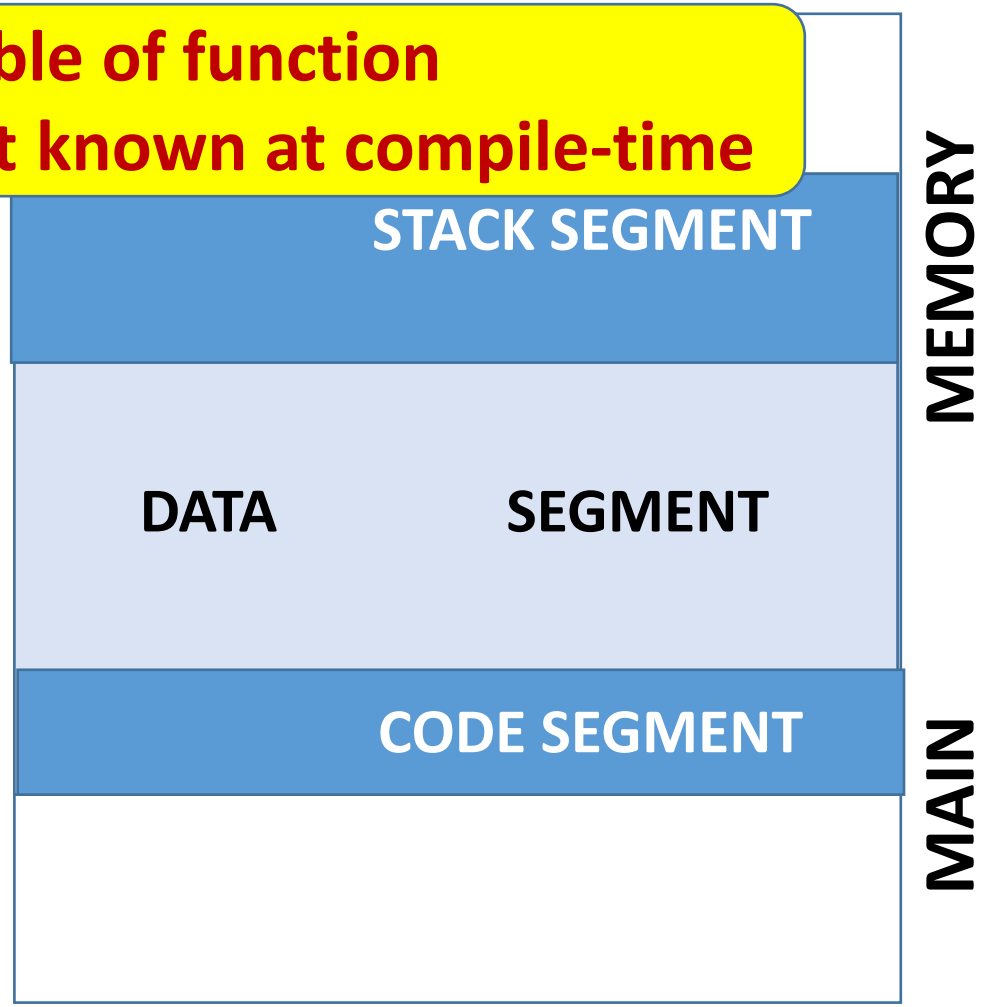
Local variable of function
Memory requirement known at compile-time



Memory For Executing A Program (Process)

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int main()
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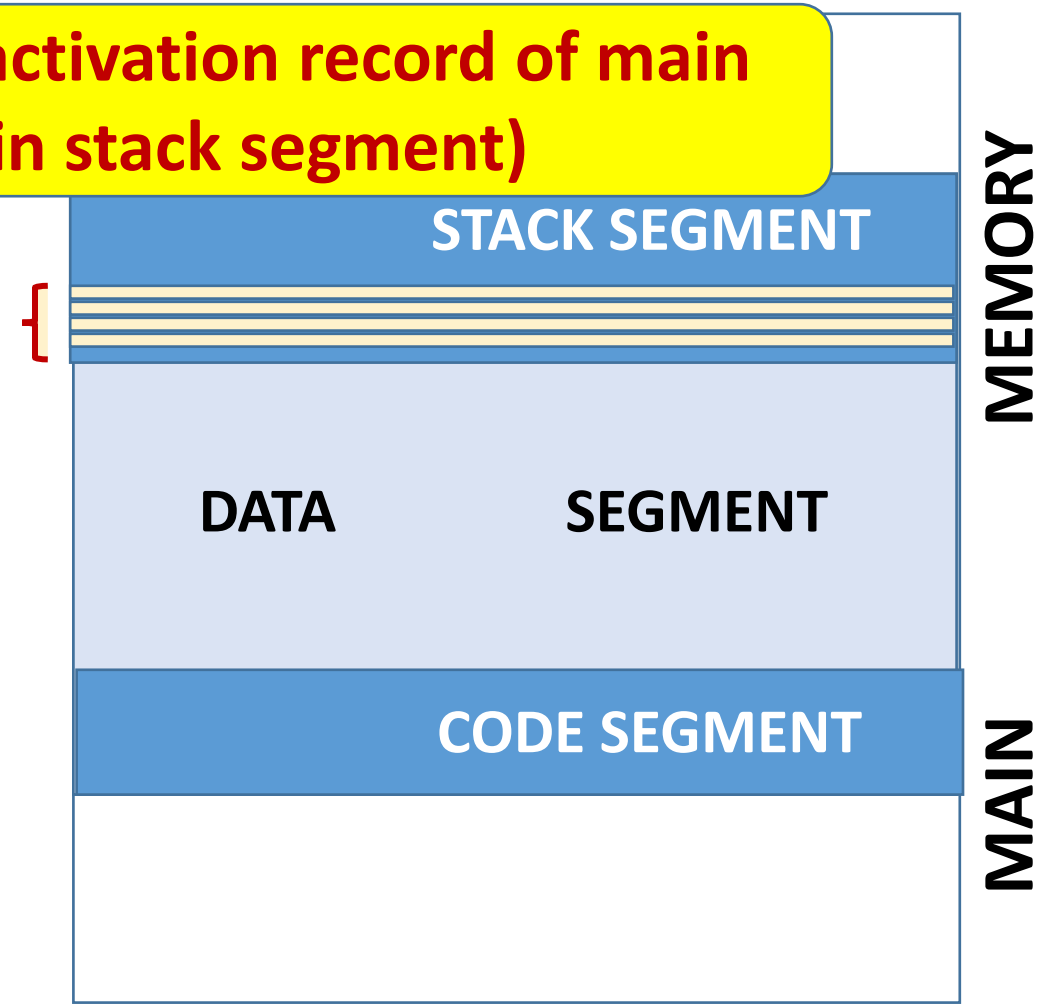
Allocate space in activation record of main (Call stack in stack segment)



Memory For Executing A Program (Process)

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```
int main()
{
   int numStude
   cin >> num dents;
  // Allocate an int array A
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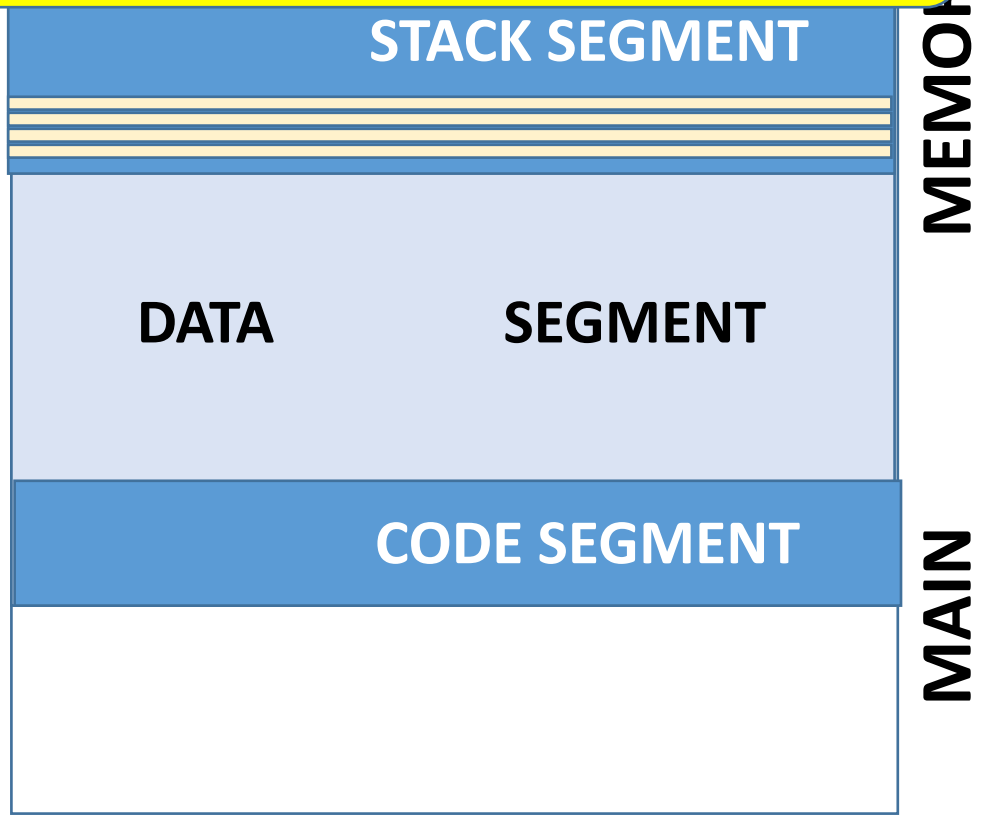
 return 0;
}
```

Size of array A dependent on value of numStudents. Memory requirement not known at compile time.



Memory For Executing A Program (Process)

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```
int main()
{
   int numStuden
   cin >> num dents;
  // Allocate an int array A
  // of size  numStudents
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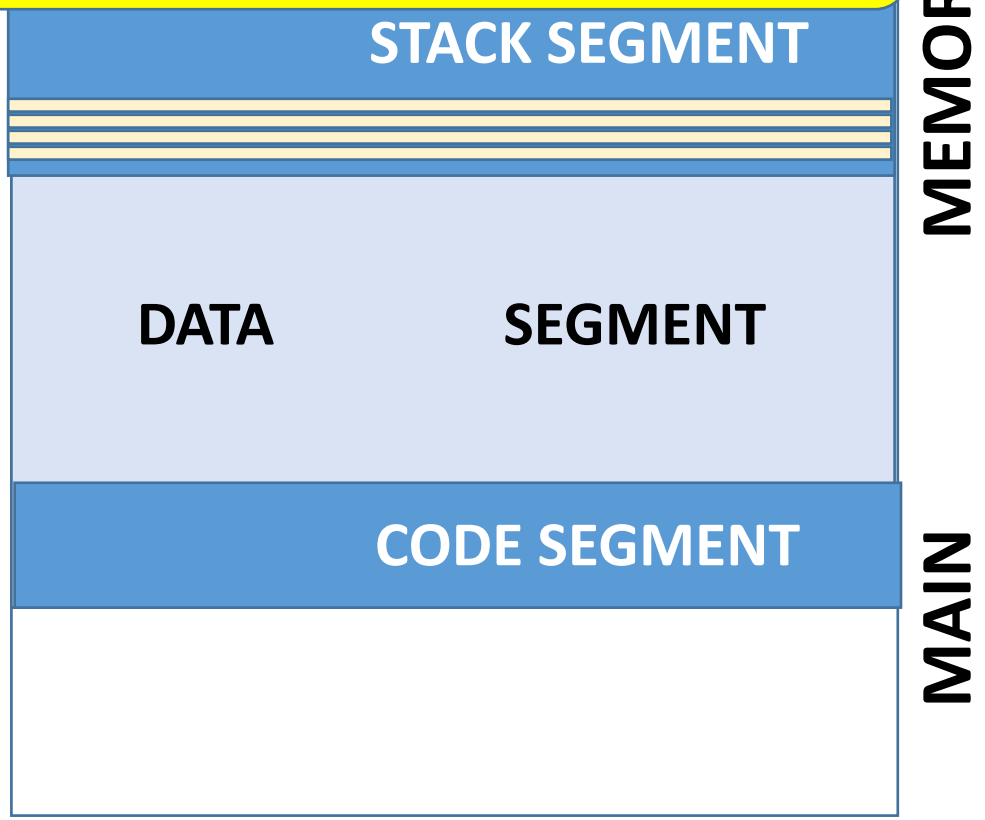
 return 0;
}
```

Cannot reserve space for array A when activation record of "main" is created in stack segment



Memory For Executing A Program (Process)

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int main
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   int numStud
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  // Allocate an int array A
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 return 0;
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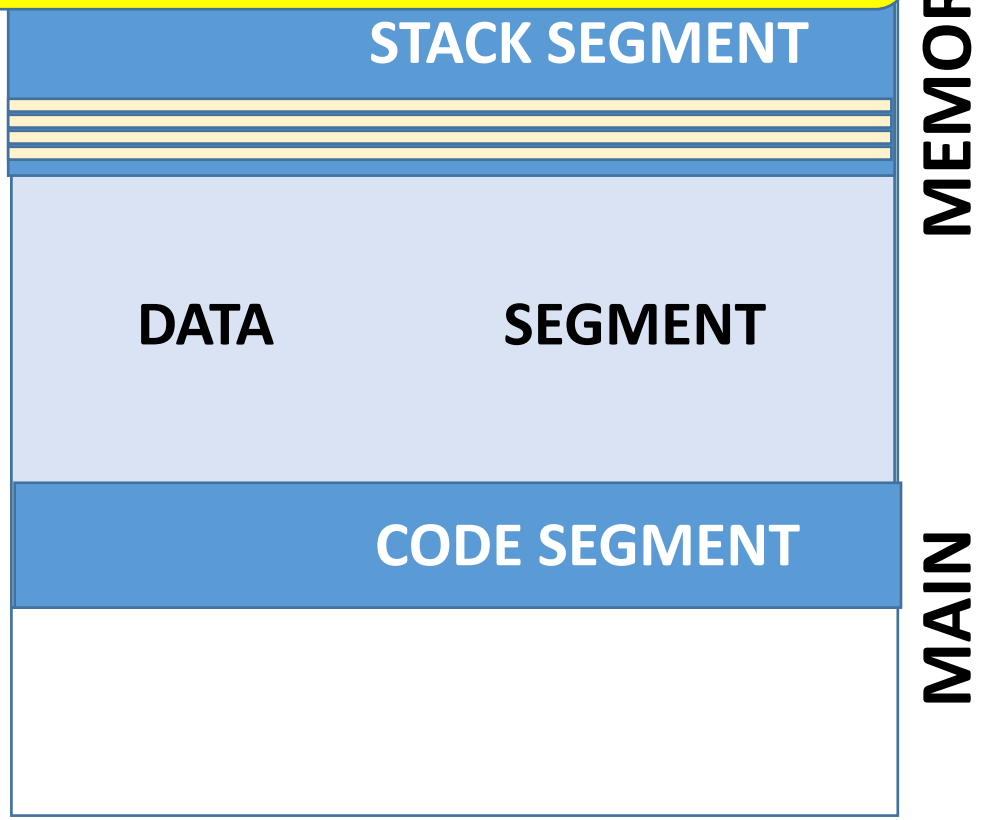
```

Where should this memory space come from?



Memory For Executing A Program (Process)

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```
int main
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   int numStud
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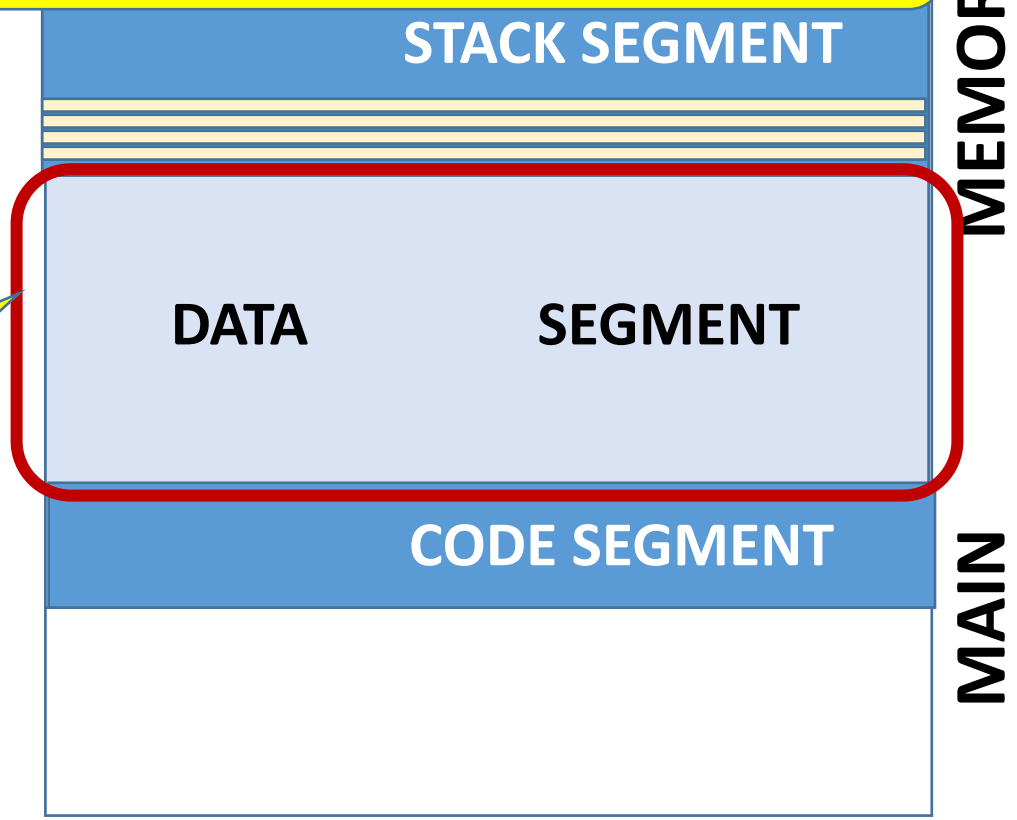
  // Allocate an int array A
  // of size  numStuden
  // S
 retu
}
```

Where should this memory space come from?

Data Segment (also called "heap") to our rescue !



Memory For Executing A Program (Process)

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int main
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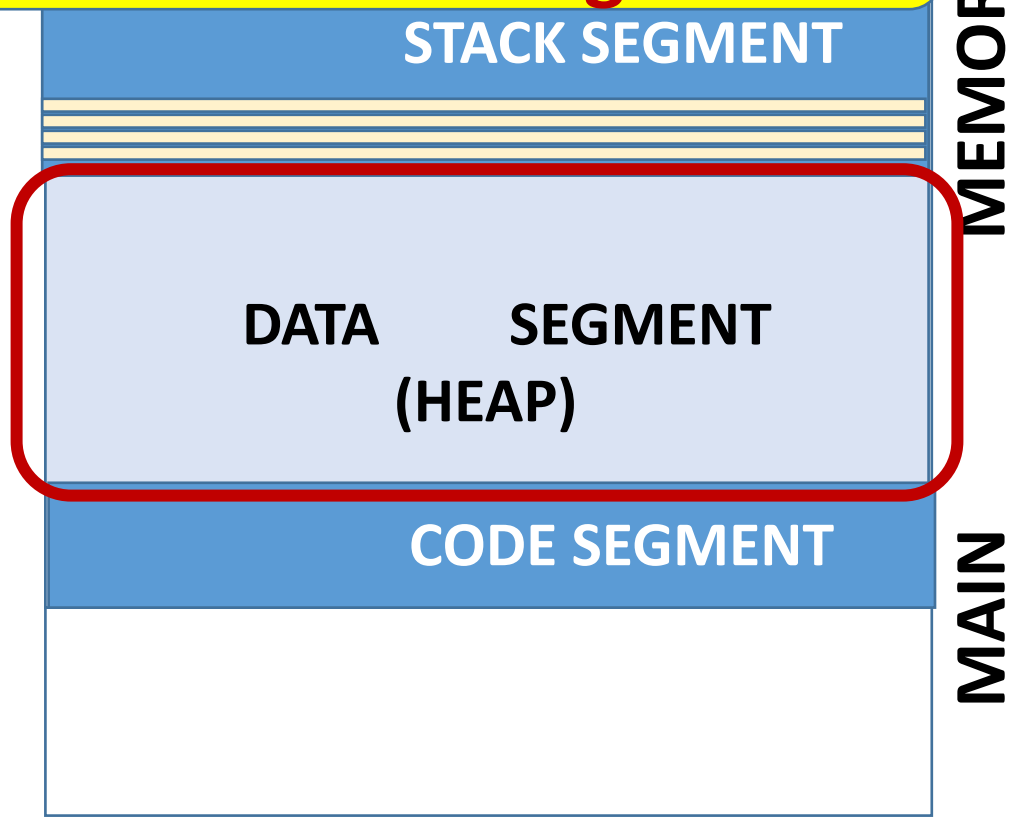
```

How do we allocate an array of size numStudents at run time in data segment?



Dynamic Memory Allocation in C++

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- C++ provides a special construct for dynamically allocating memory in heap (data segment)

```
A = new int [numStudents];
```

Dynamically allocate memory on heap

Dynamic Memory Allocation in C++

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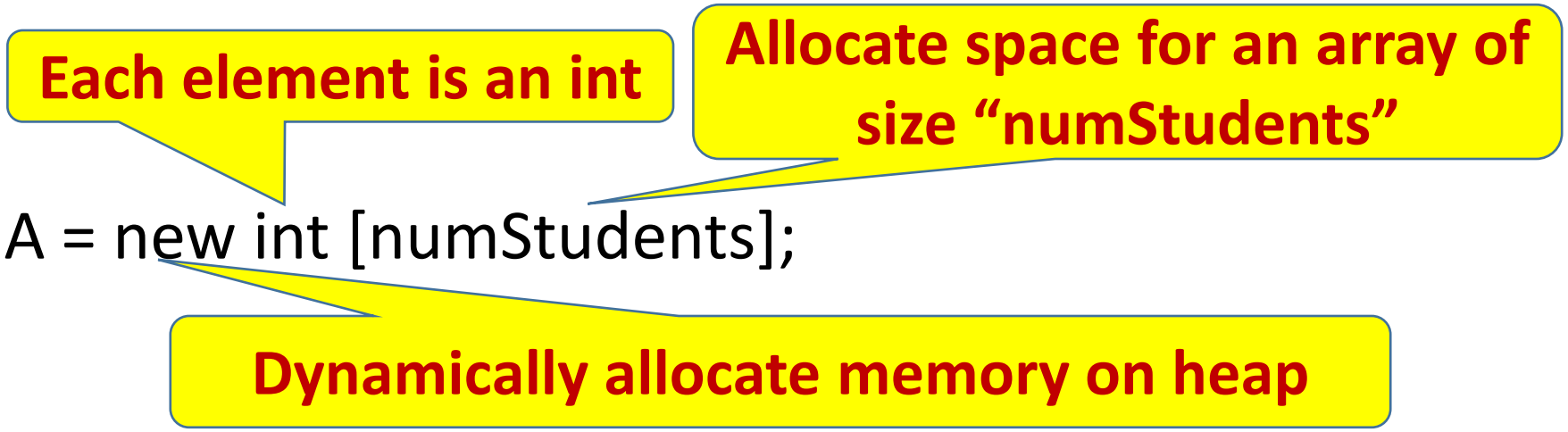
- C++ provides a special construct for dynamically allocating memory in heap (data segment)



Dynamic Memory Allocation in C++

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- C++ provides a special construct for dynamically allocating memory in heap (data segment)

Returns pointer to an int

```
A = new int [numStudents];
```

A should be of type int *

Memory For Executing A Program (Process)

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```
int main()
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   int * A;
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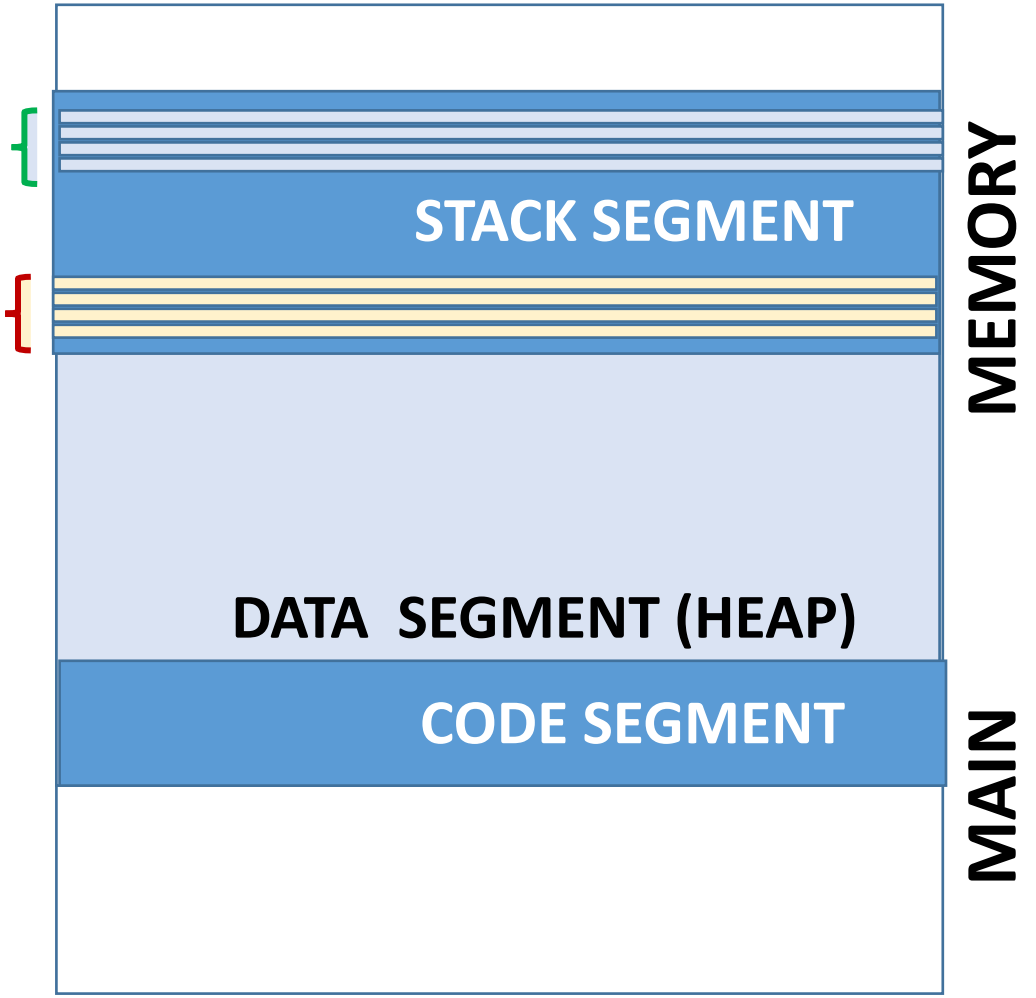

Memory For Executing A Program (Process)

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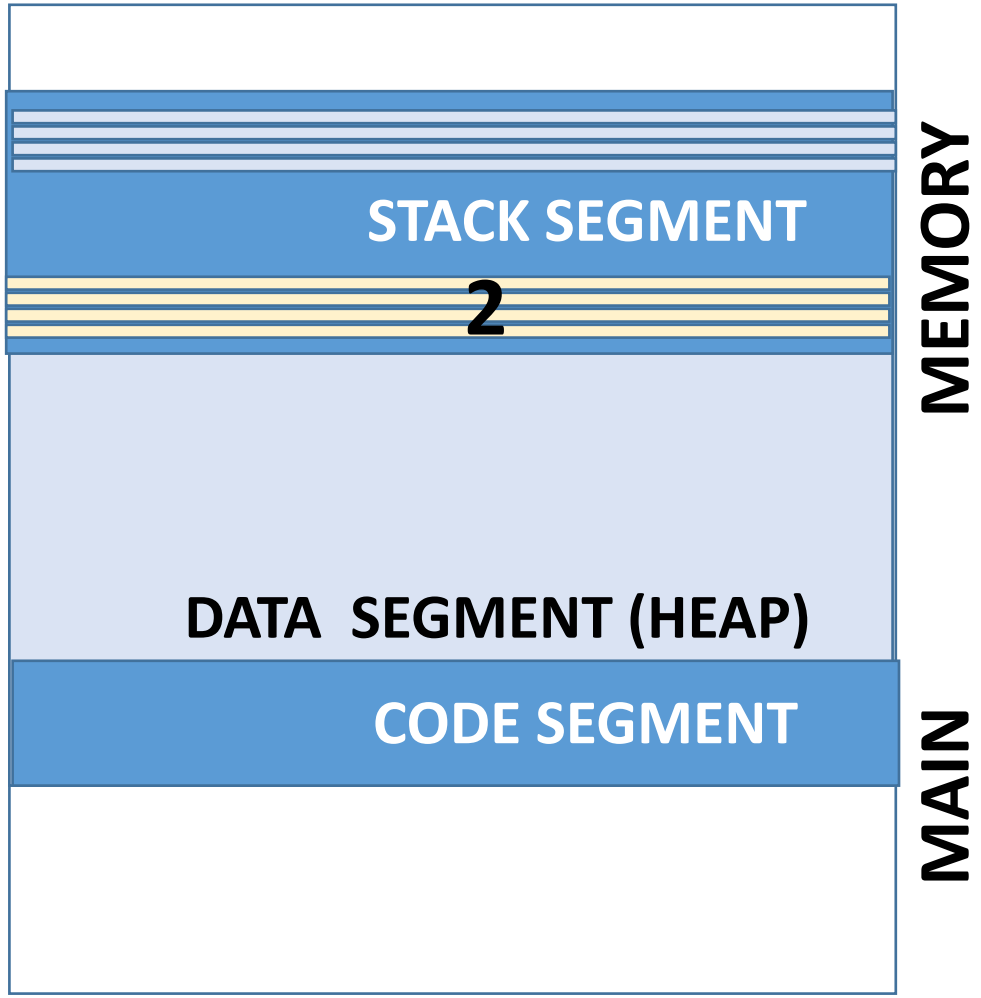

Memory For Executing A Program (Process)

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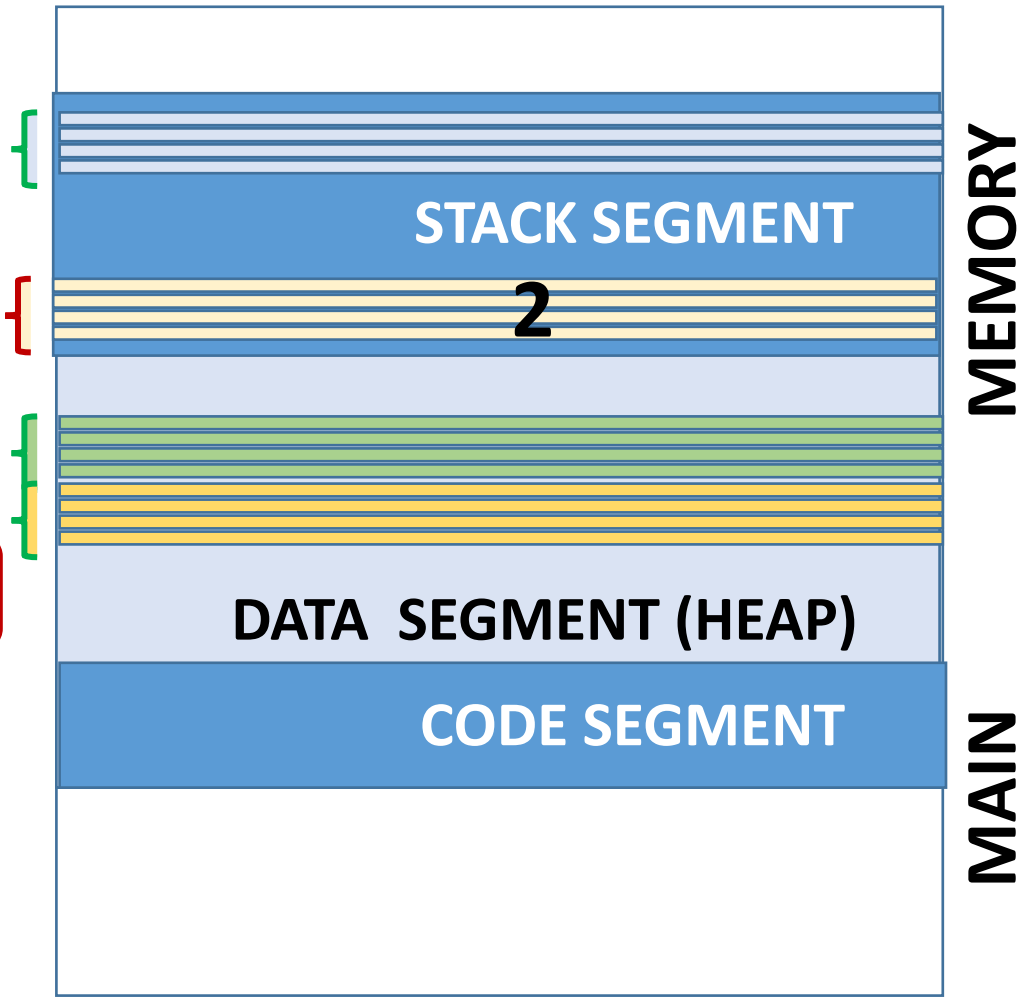

Memory For Executing A Program (Process)

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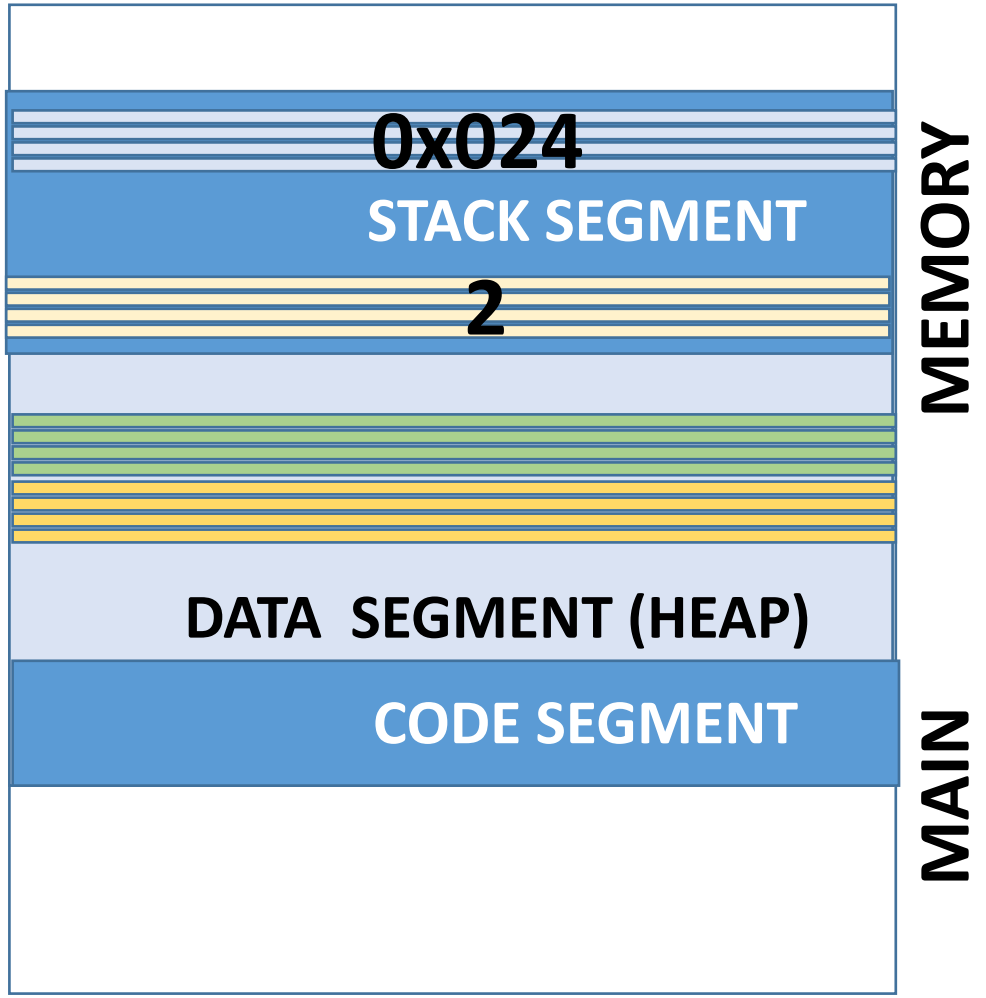

Memory For Executing A Program (Process)

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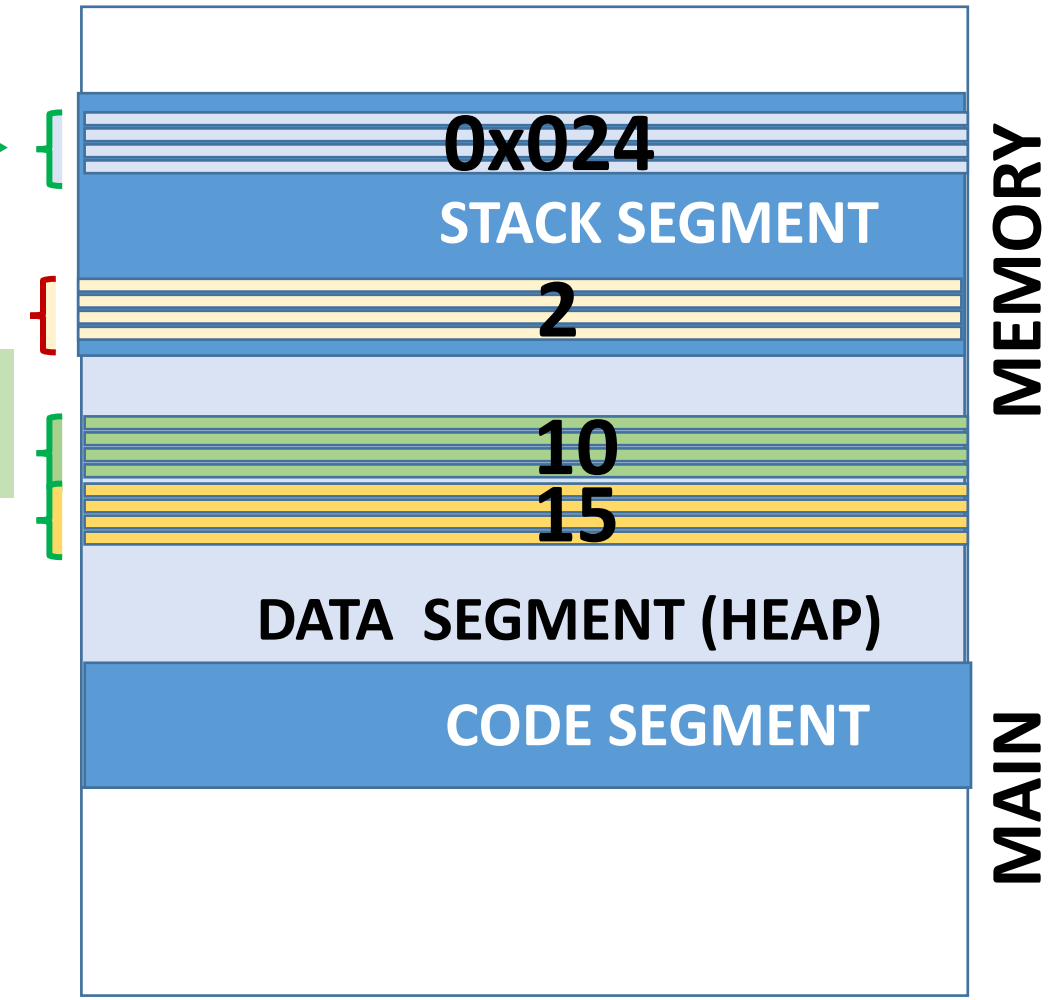
```
int main()
{
   int numStudents;
   int * A;
   cin >> numStudents;
   A = new int[numStudents];
   A[0] = 10; A[1] = 15;
 return 0;
}
```



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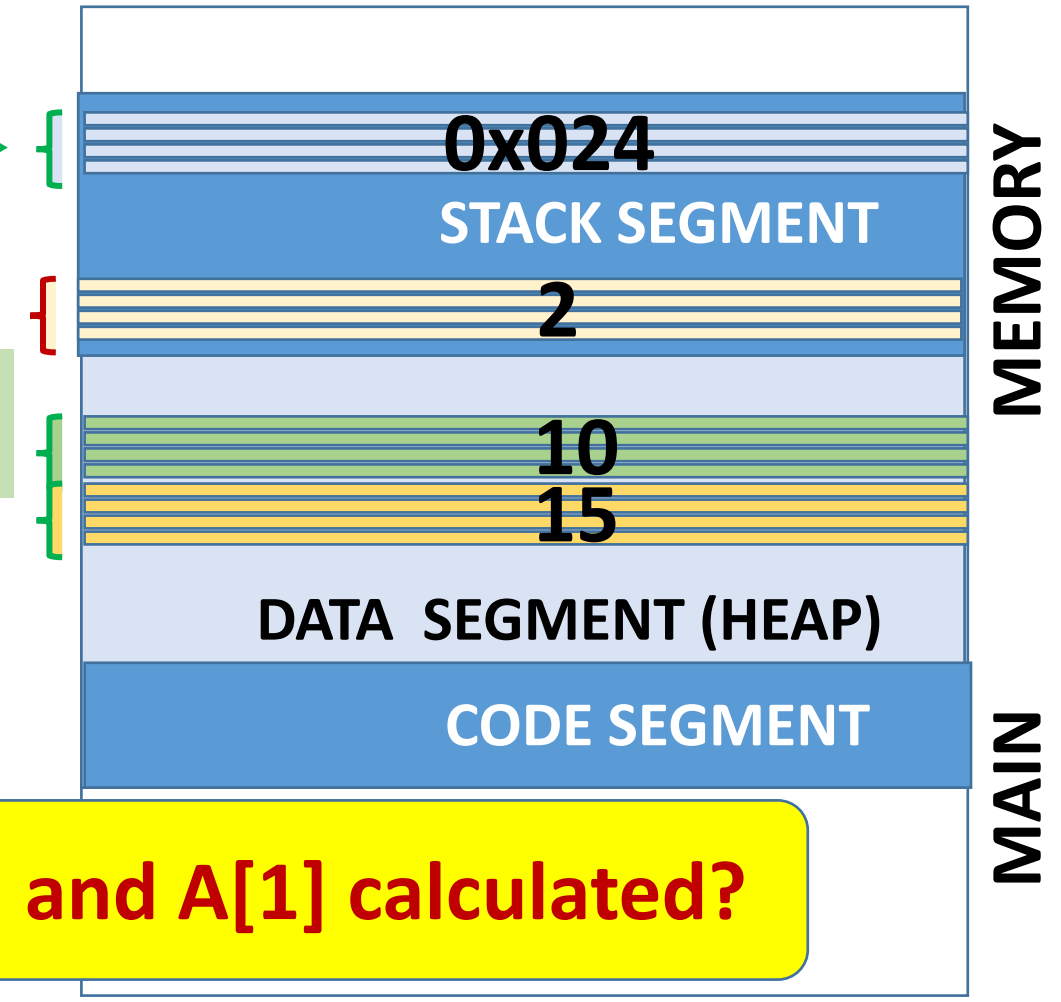

How are addresses of A[0] and A[1] calculated?

Calculating Addresses for Dynamic Arrays

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- Compiler knows
  - A is pointer to an integer that is the first in an array of integers
    - How? From "**A = new int[numStudents];**"
  - Each element of the array is of **int** data type
  - Each int takes 4 consecutive memory locations (bytes)
- Therefore,
  - Address of A[0] is (A + 0)
  - Address of A[i] is (A + (4*i))

Address Arithmetic

Generic Format for Dynamic Memory Allocation

- To dynamically allocate memory for a variable of type T

  T * myVarPtr;

  myVarPtr = new T;

  Variable accessed as ***myVarPtr**

- To dynamically allocate memory for an array of n elements of type T

  T * myArray;

  myArray = new T[n];

  Array elements accessed as **myArray[0] … myArray[n-1]**

Generic Format for Dynamic Memory Allocation

- To dynamically allocate memory for a variable of type T

  T * myVarPtr;

  myVarPtr = new T;

  Variable accessed as ***myVar**

- To dynamically allocate m… of type T

  T * myArray;

  myArray = new T[n];

  Array elements accessed as **myArray[0] … myArray[n-1]**

"new" returns pointer to T in both cases

Array of type T treated as a variable of type T * that can be indexed using […]

Good Programming Practices

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- Most often, “new” will successfully allocate requested memory from heap and return address to the first allocated byte
- **However, we cannot take “new” for guaranteed**
  - **C++ allows “new” to fail and return 0x0 (also called NULL pointer)**
- **Always check if “new” has returned an address other than 0x0 (NULL) before dereferencing that address**
  - Avoids unnecessary program crashes especially if program dynamically allocates too much memory
  - This is real !!! Programmers encounter this situation in real-life

Dynamic Memory Allocation: The Right Way

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```
int main()
{
   int numStudents;
   int * A;
   cin >> numStudents;
   A = new int[numStudents];
   if (A != NULL) { A[0] = 10; A[1] = 15;}
   return 0;
}
```

Note the check for "new" having succeeded

Summary

- Dynamically allocating memory on heap (data segment)
- “new” construct in C++
- Accessing dynamically allocated variables and arrays
- Good programming practices when using dynamically allocated memory