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# Computer Programming

Dr. Deepak B Phatak
Dr. Supratik Chakraborty
Department of Computer Science and Engineering
IIT Bombay

## Session: Introduction to Pointers – Part 2

# Quick Recap of Relevant Topics

- Basic programming constructs
- Pointer data type in C++
- “Address of” operator in C++
- Caveats when using “address of” operator

# Overview of This Lecture

- Dereferencing a memory address
  - Finding content at a given memory address
- “Contents of” operator in C++

# Memory and Addresses

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- Memory is a sequence of physical storage locations
- Each location stores 1 byte (8 bits): **Content/value** of location
- Each physical memory location identified by a unique **address**
  - **Index in sequence of memory locations**

**Address (in hexadecimal)**

| | |
|---|---|
| **400** | 1 0 0 1 1 1 0 1 |
| **401** | 1 0 1 1 1 1 1 1 |
| **402** | 1 0 0 1 0 0 0 1 |
| **403** | 1 0 1 1 0 1 1 1 |
| **404** | 1 0 0 1 0 0 0 1 |
| **405** | 1 0 0 0 0 1 1 1 |
| **406** | 1 1 1 1 0 0 0 1 |
| **407** | 1 0 0 0 0 0 0 0 |
| **408** | 1 1 1 1 1 1 1 1 |
| **409** | 0 0 0 0 0 0 0 0 |
| **40a** | 1 1 1 1 0 0 0 0 |

# Memory For Executing A Program (Process)

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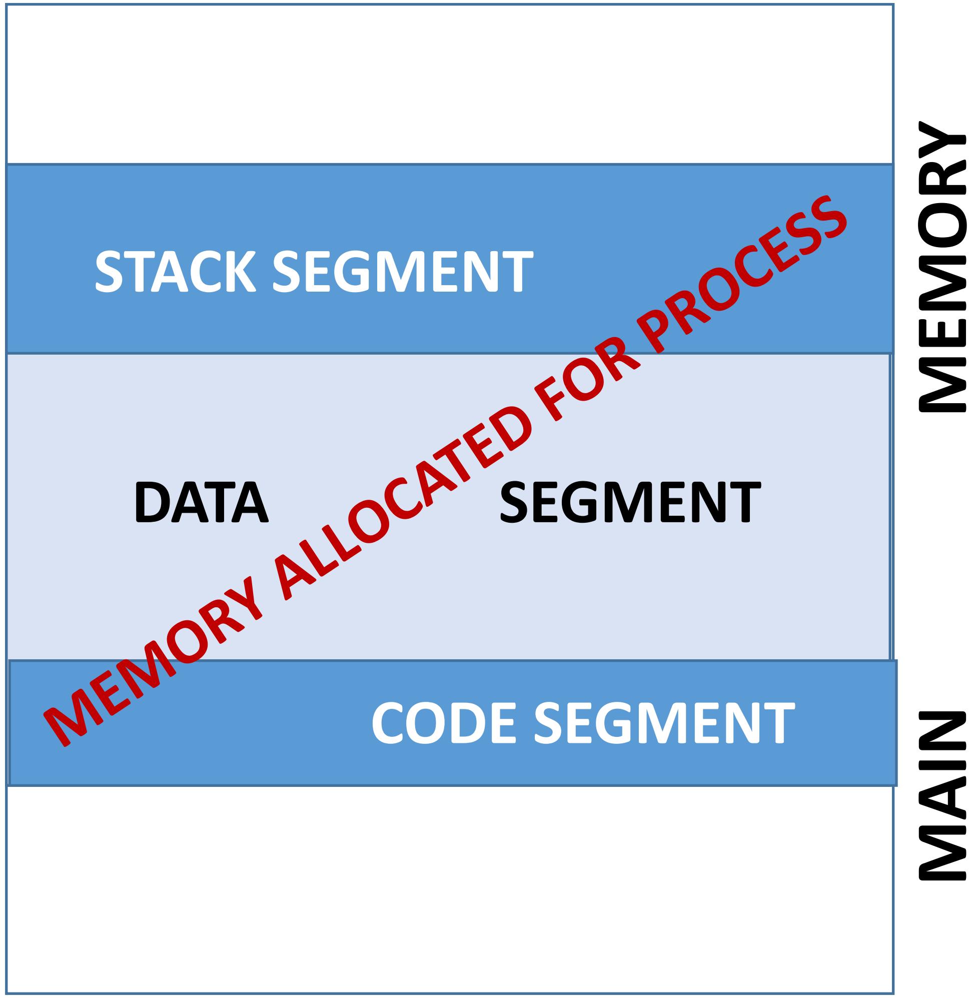
- Operating system allocates a part of main memory for use by a process
- Divided into:

  **Code segment**: Stores executable instructions in program

  **Data segment**: For dynamically allocated data (later lecture)

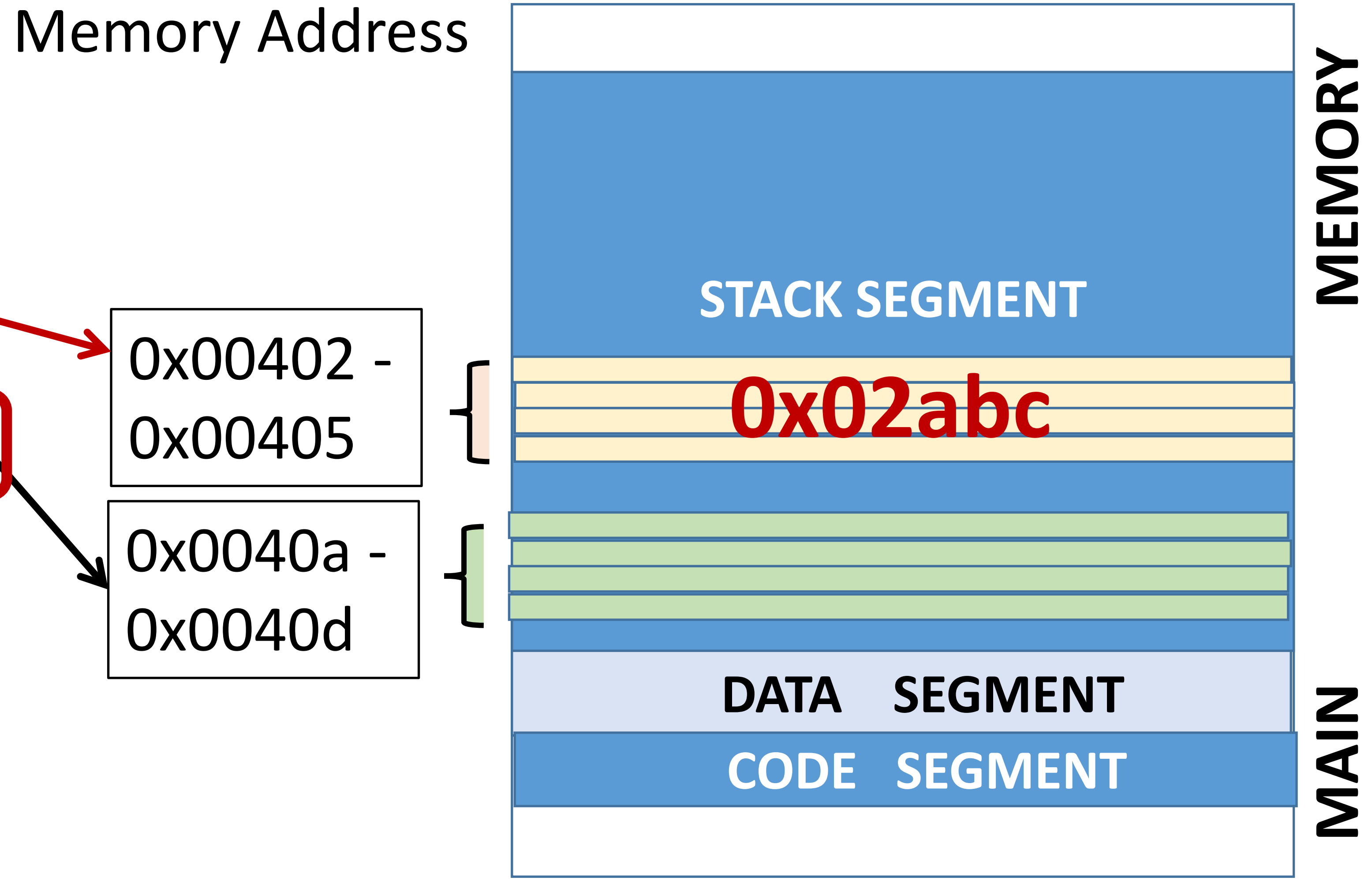
  **Stack segment**: Call stack



# Accessing Content At Given Address

```
int main()
{
   int a;
   int * ptrA;
   a = 0x02abc;
   ptrA = &a;

// Rest of code
}
```



# Accessing Content At Given Address

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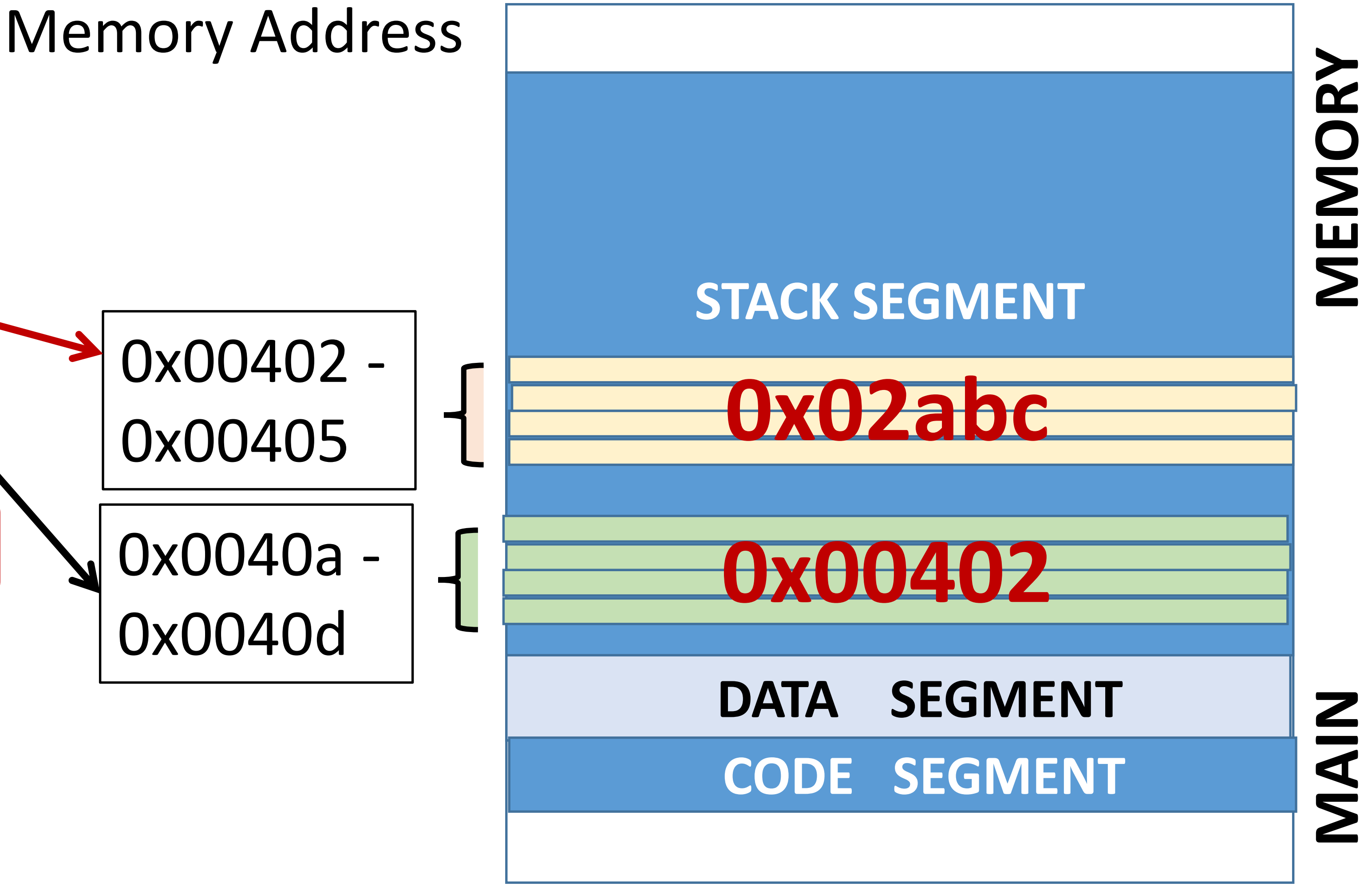
```
int main()
{
   int a;
   int * ptrA;
   a = 0x02abc;
   ptrA = &a;

// Rest of code
}
```



# Accessing Content At Given Address

```
int main()
{
   int a;
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   a = 0x02abc;
   ptrA = &a;

// Rest of code
}
```
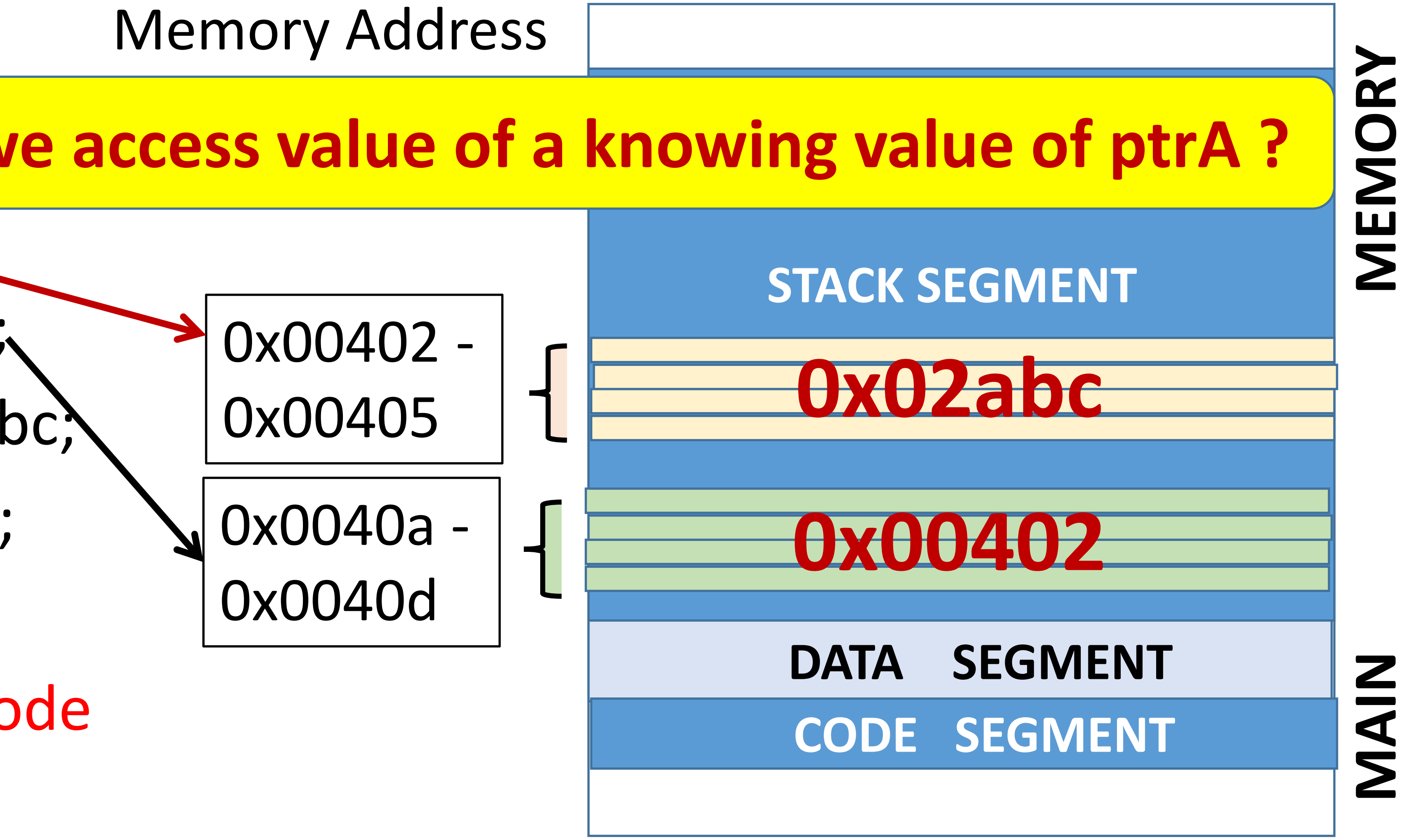



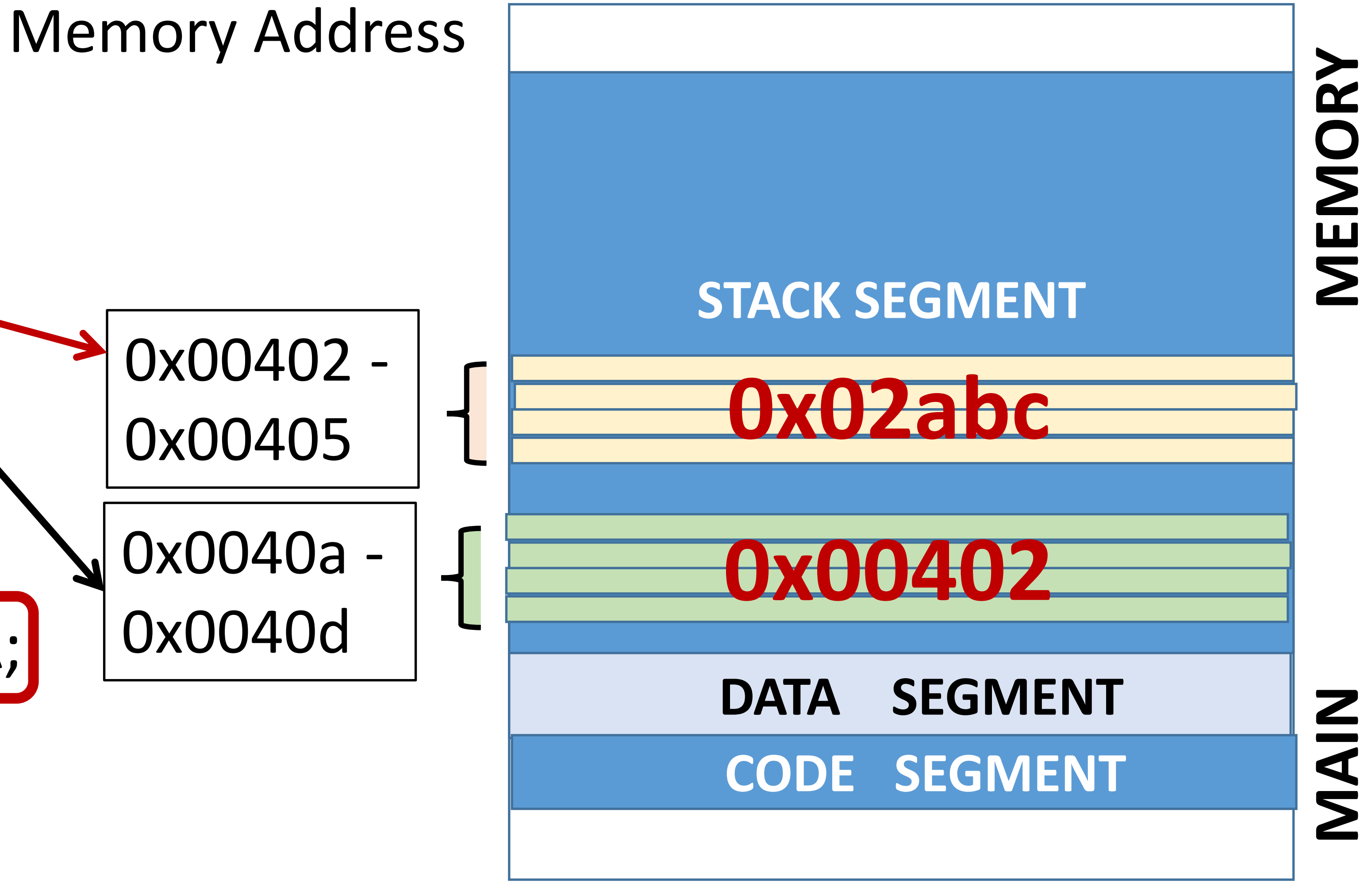
**Can we access value of a knowing value of ptrA ?**

# Accessing Content At Given Address

- C++ provides a “content of” operator: unary *
  - If “ptrA” is a program variable of type “int *”, “* ptrA” gives the integer stored at address given by “ptrA”

# Accessing Content At Given Address

```
int main()
{
   int a;
   int * ptrA;
   a = 0x02abc;
   ptrA = &a;
   cout << *ptrA;
// Rest of code
}
```



# Accessing Content At Given Address

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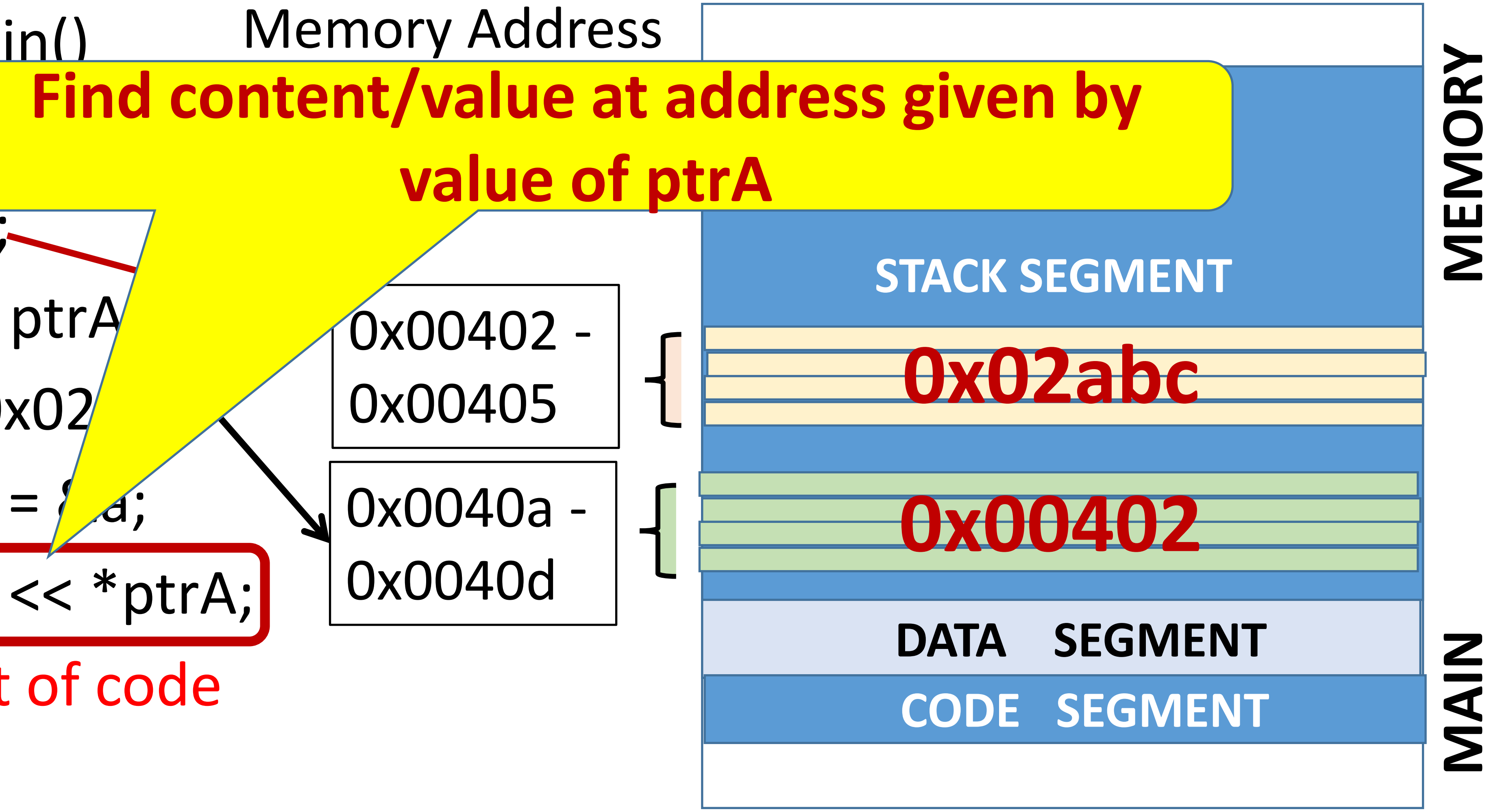
```
int main()
{
   int a;
   int * ptrA
   a = 0x02
   ptrA = &a;
   cout << *ptrA;
// Rest of code
}
```



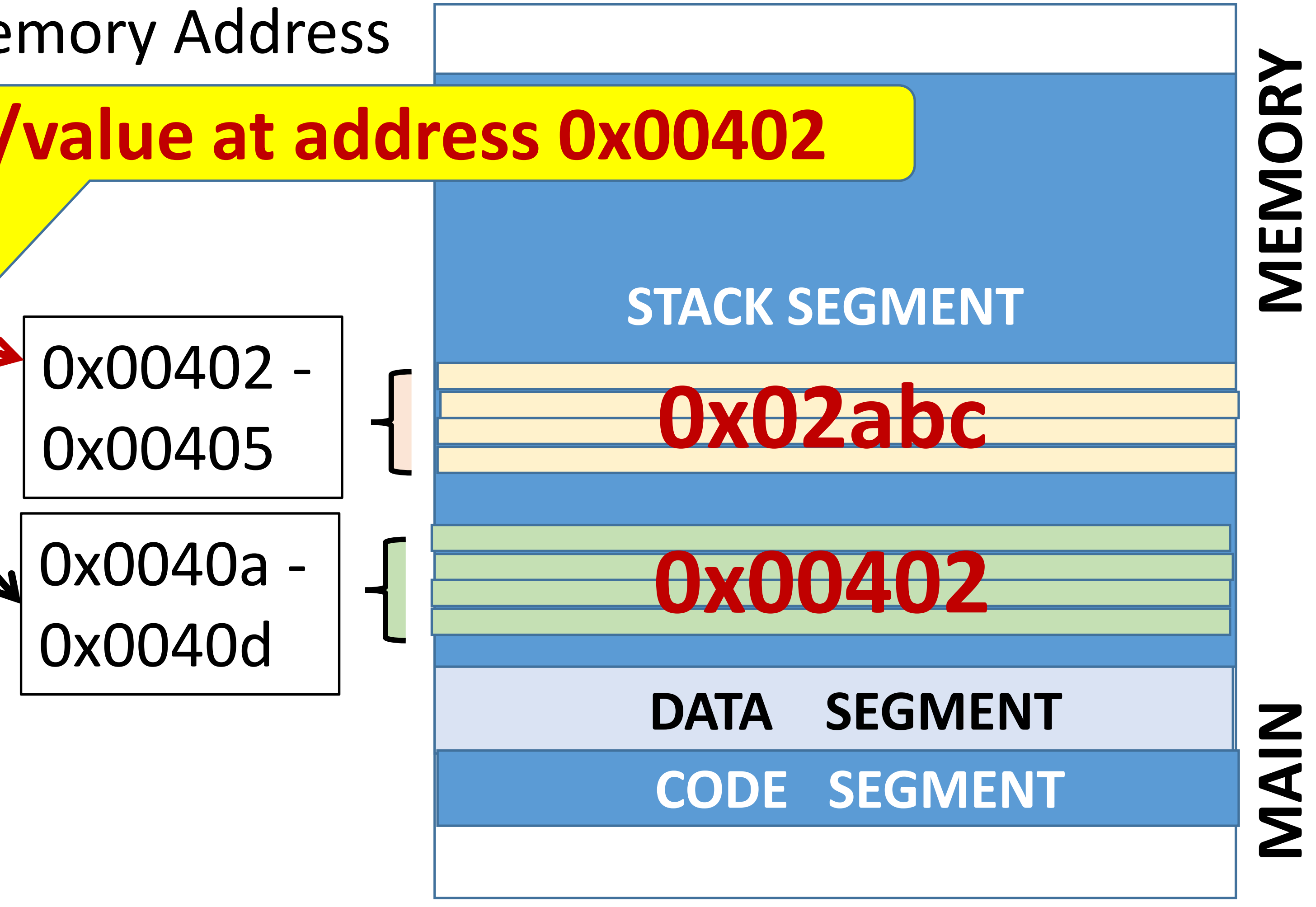
Find content/value at address given by value of ptrA

# Accessing Content At Given Address

```
int main()
{
  int a;
  int * pt
  a = 0x(     c;
  ptrA = &a;
  cout << *ptrA;
// Rest of code
}
```

Find content/value at address 0x00402

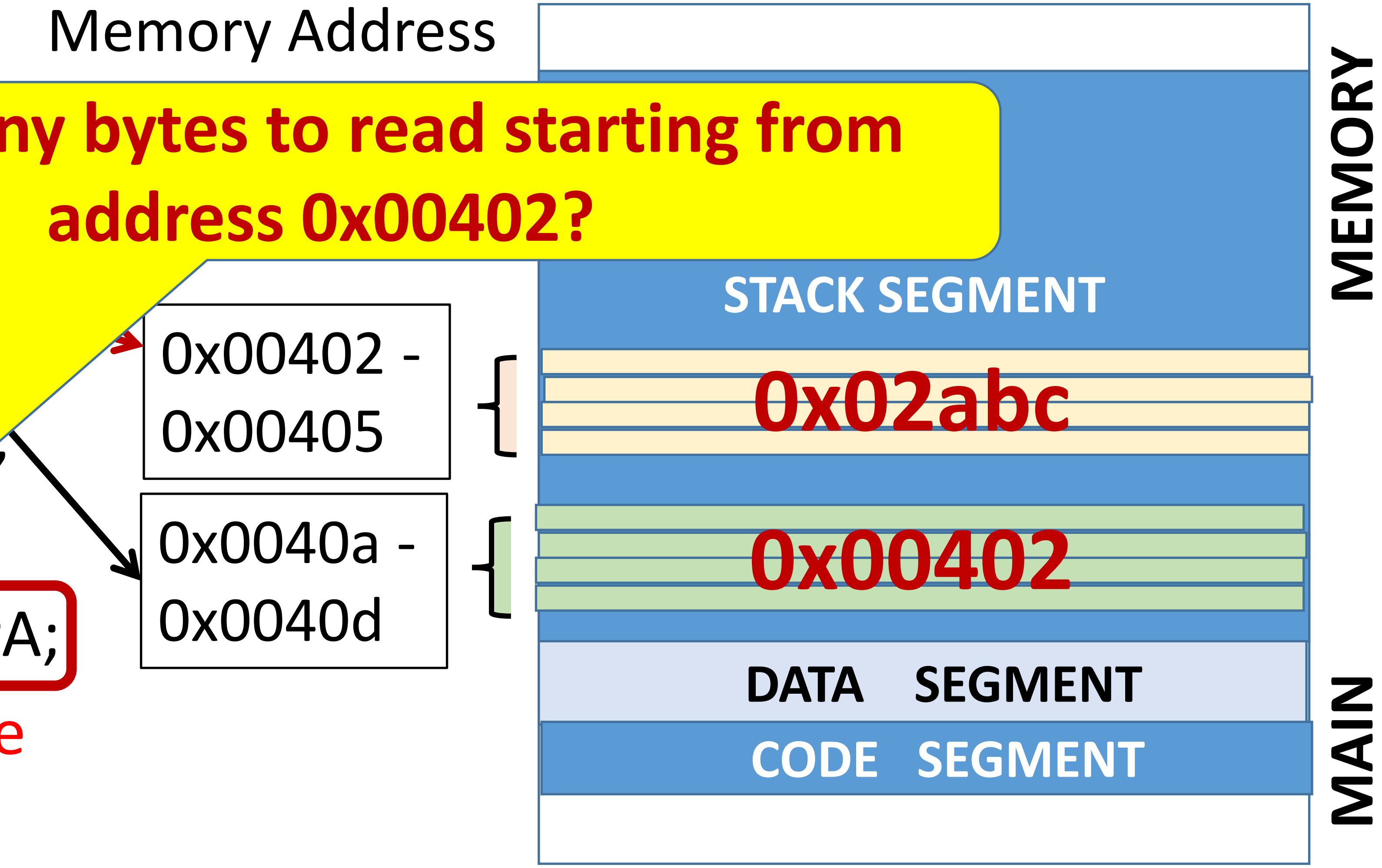
Memory Address



# Accessing Content At Given Address

```
int main()
{
  int * pt
  a = 0x0
  ptrA =  a;
  cout << *ptrA;
// Rest of code
}
```

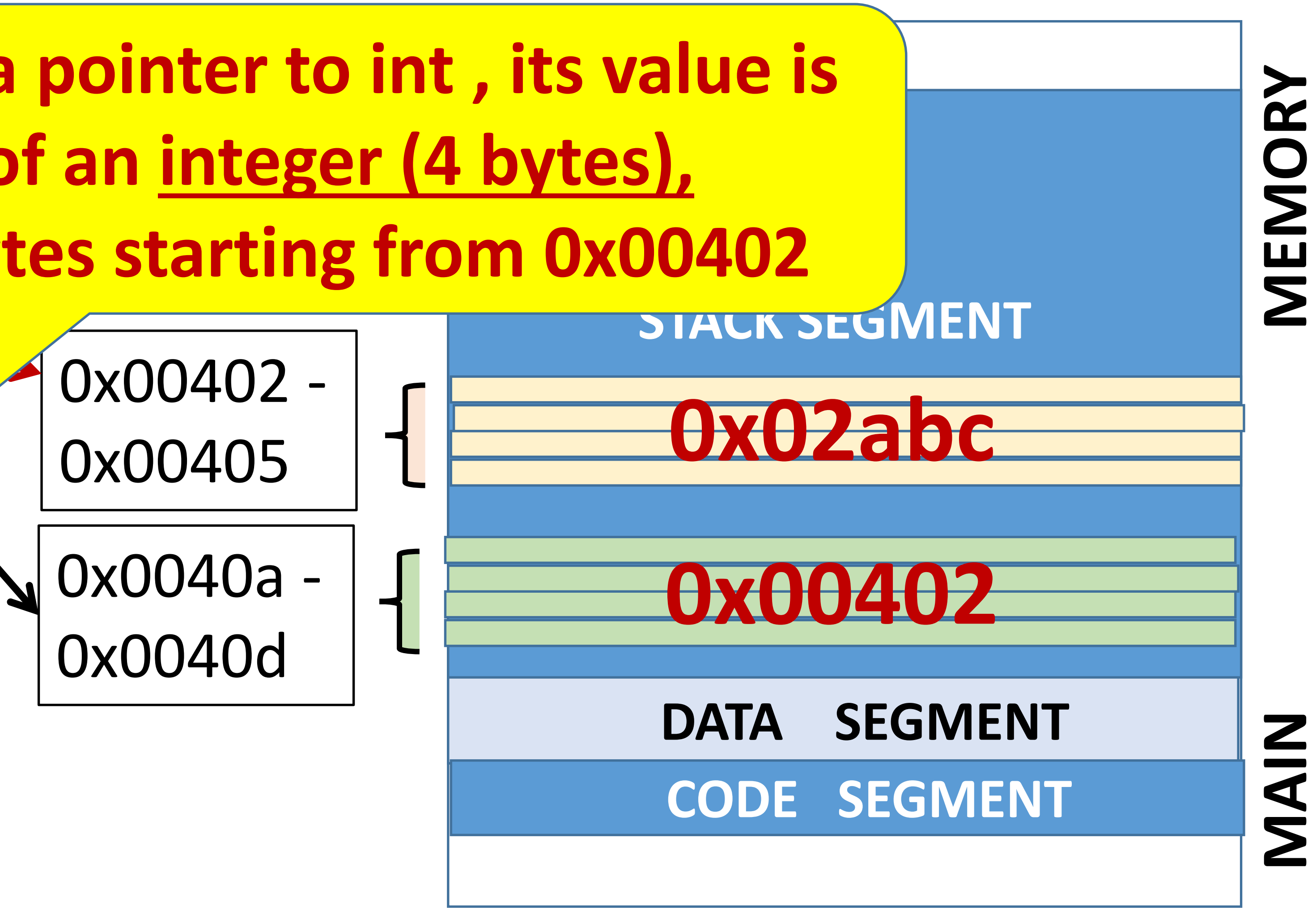
**How many bytes to read starting from address 0x00402?**



# Accessing Content At Given Address

**Since ptrA is a pointer to int , its value is address of an <u>integer (4 bytes),</u> so read 4 bytes starting from 0x00402**

```
i
{
  int * pt
  a = 0x(      ;
  ptrA = &a;
  cout << *ptrA;
// Rest of code
}
```



# Accessing Content At Given Address

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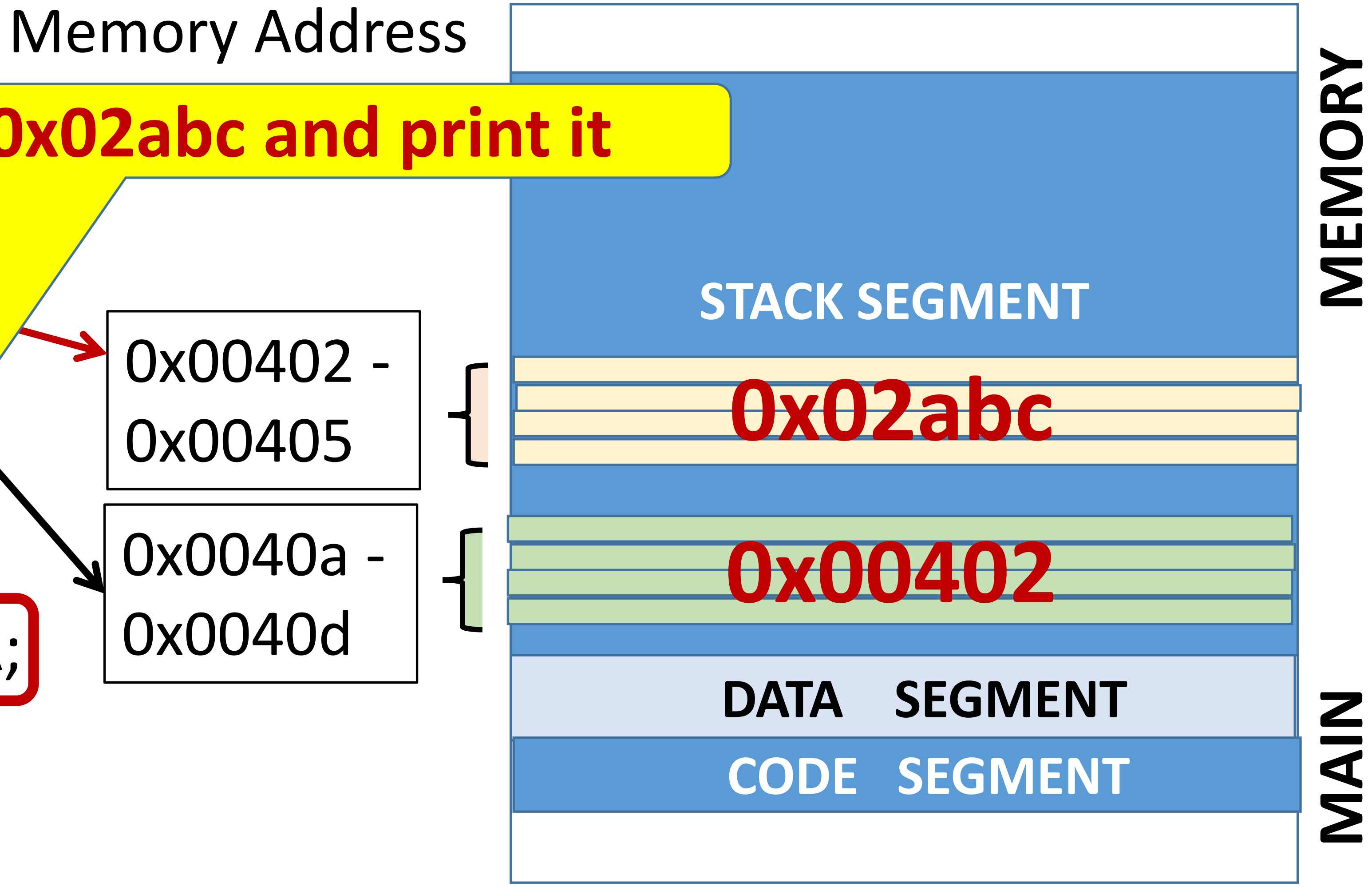
```
int main()
{
   int a;
   int * ptr
   a = 0x02     c;
   ptrA = &  a;
   cout << *ptrA;
// Rest of code
}
```

**Read 0x02abc and print it**



# Accessing Content At Given Address

- C++ provides a “content of” operator: unary *
  - “*ptrA” gives the content at address given by “ptrA”
  - Unary operator: Takes a single argument
  - “* ptrA” is a C++ expression

    Worry about operator precedence, associativity???

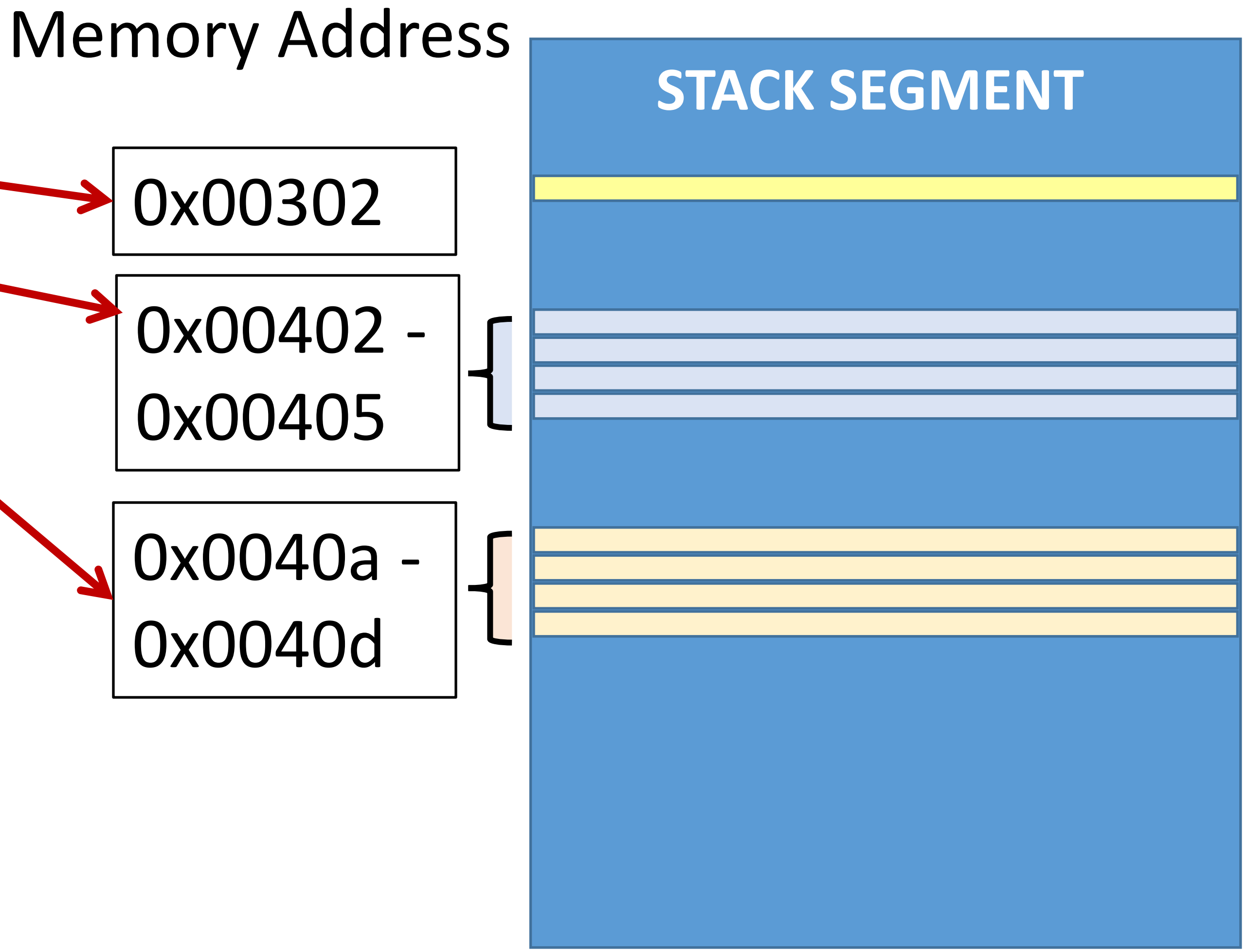
    Simplify life: use parentheses

**“Dereferencing an address”: Accessing content at that address**

**Can have spaces after “&” and “*”: use carefully**
**Which is more understandable? &a or & a, *ptrA or * ptrA**

# Can We Have Dereferences of Dereferences?

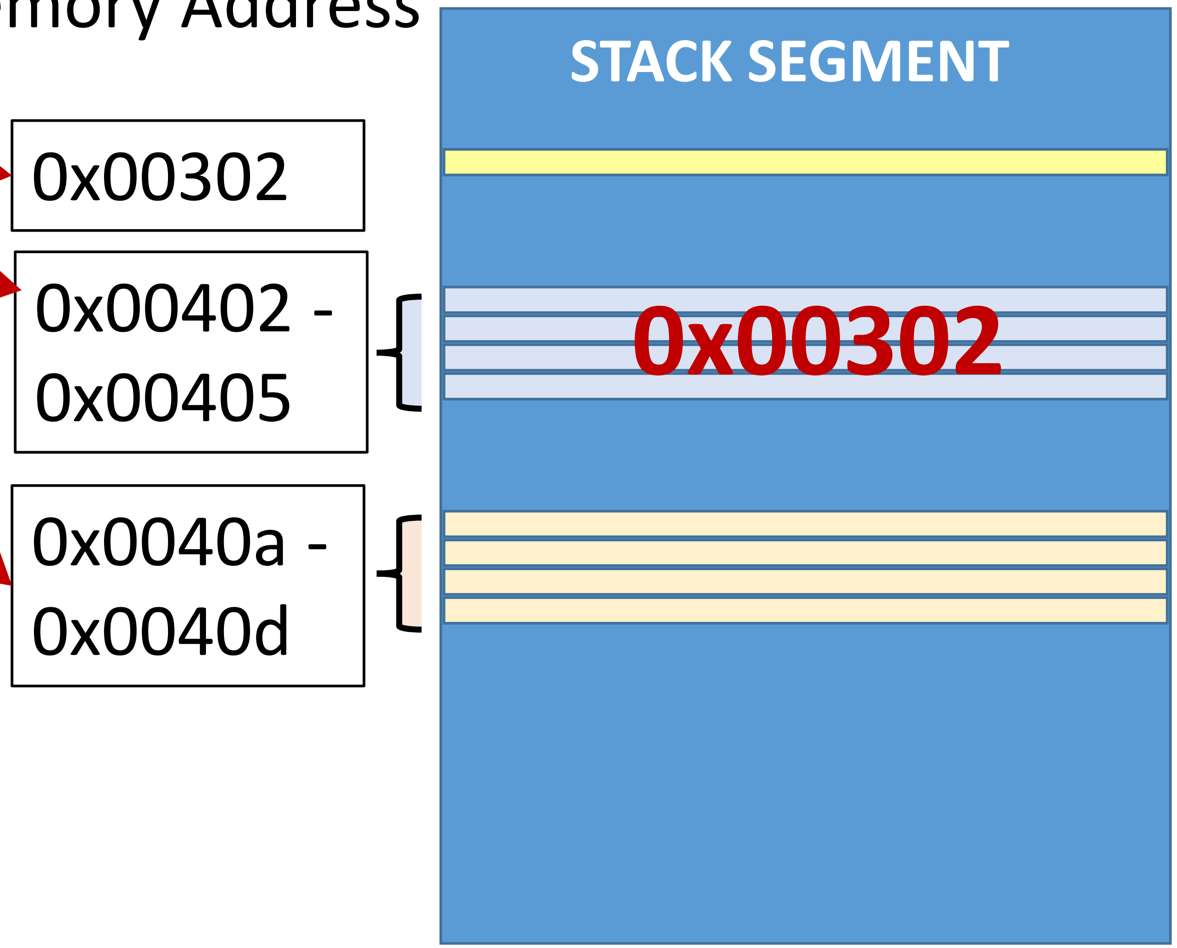
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



# Can We Have Dereferences of Dereferences?

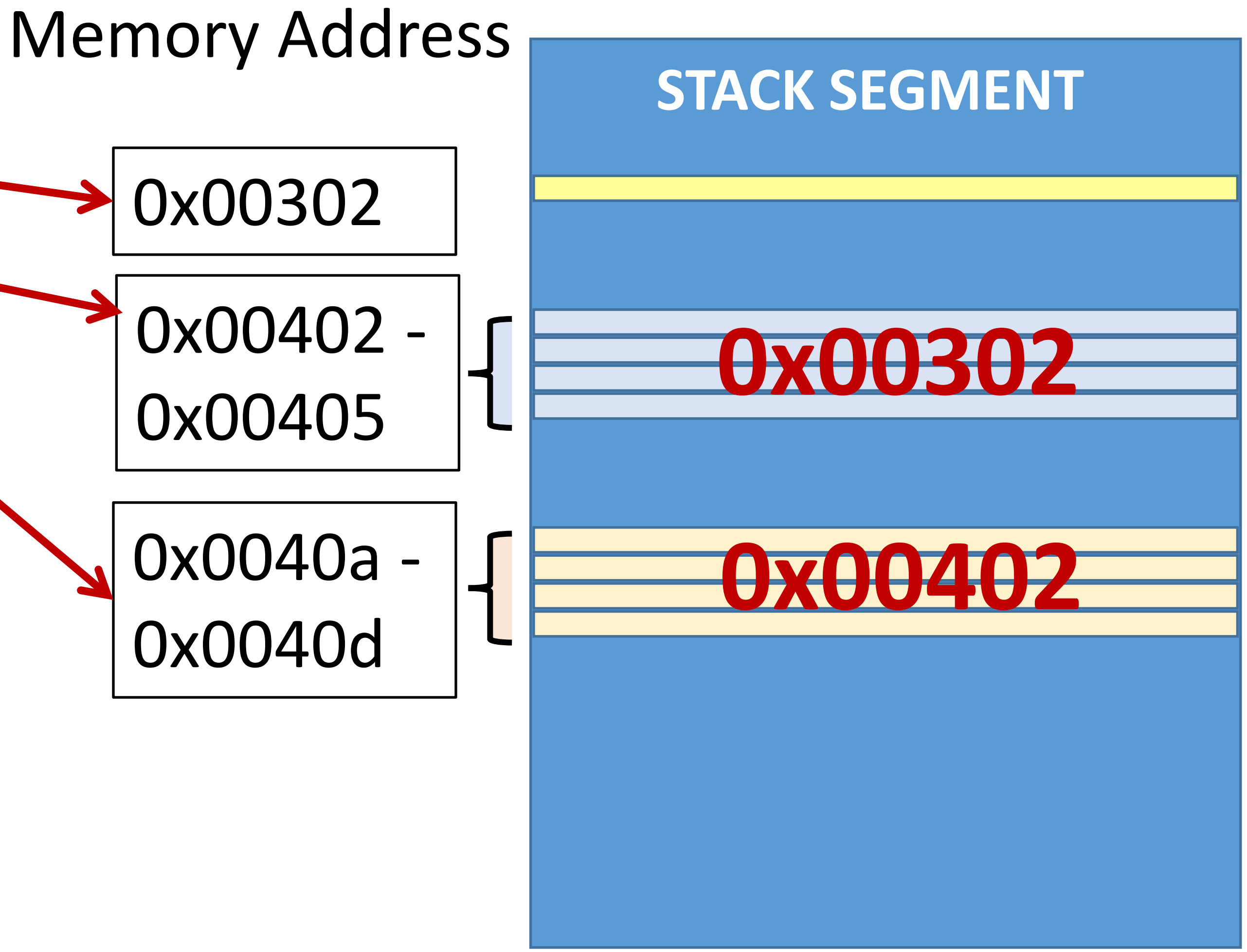
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```

Memory Address



# Can We Have Dereferences of Dereferences?

```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



Memory Address

0x00302

0x00402 - 0x00405

0x0040a - 0x0040d

STACK SEGMENT

0x00302

0x00402

# Can We Have Dereferences of Dereferences?

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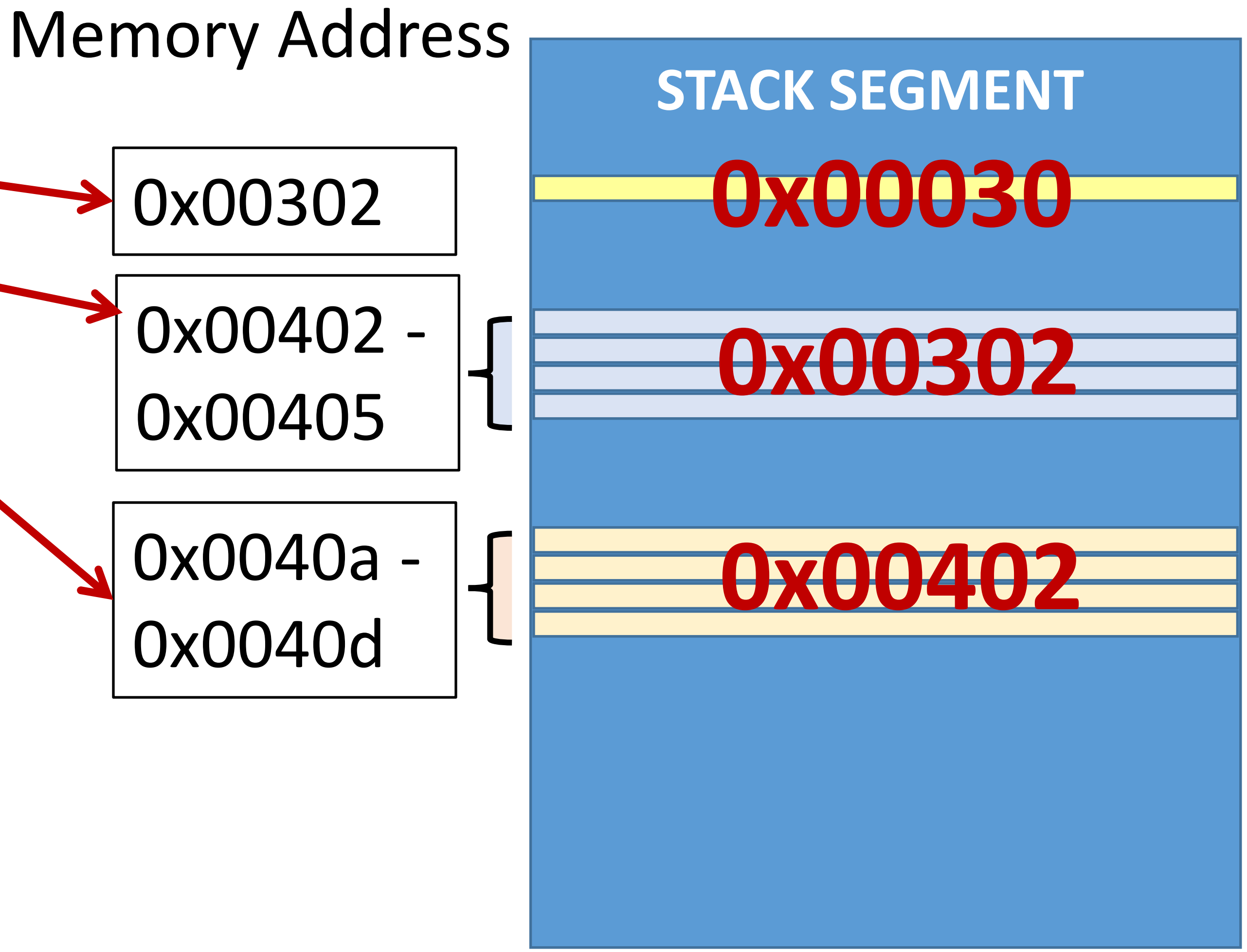
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



Memory Address

0x00302

0x00402 -
0x00405

0x0040a -
0x0040d

STACK SEGMENT

0x00030

0x00302

0x00402

# Can We Have Dereferences of Dereferences?

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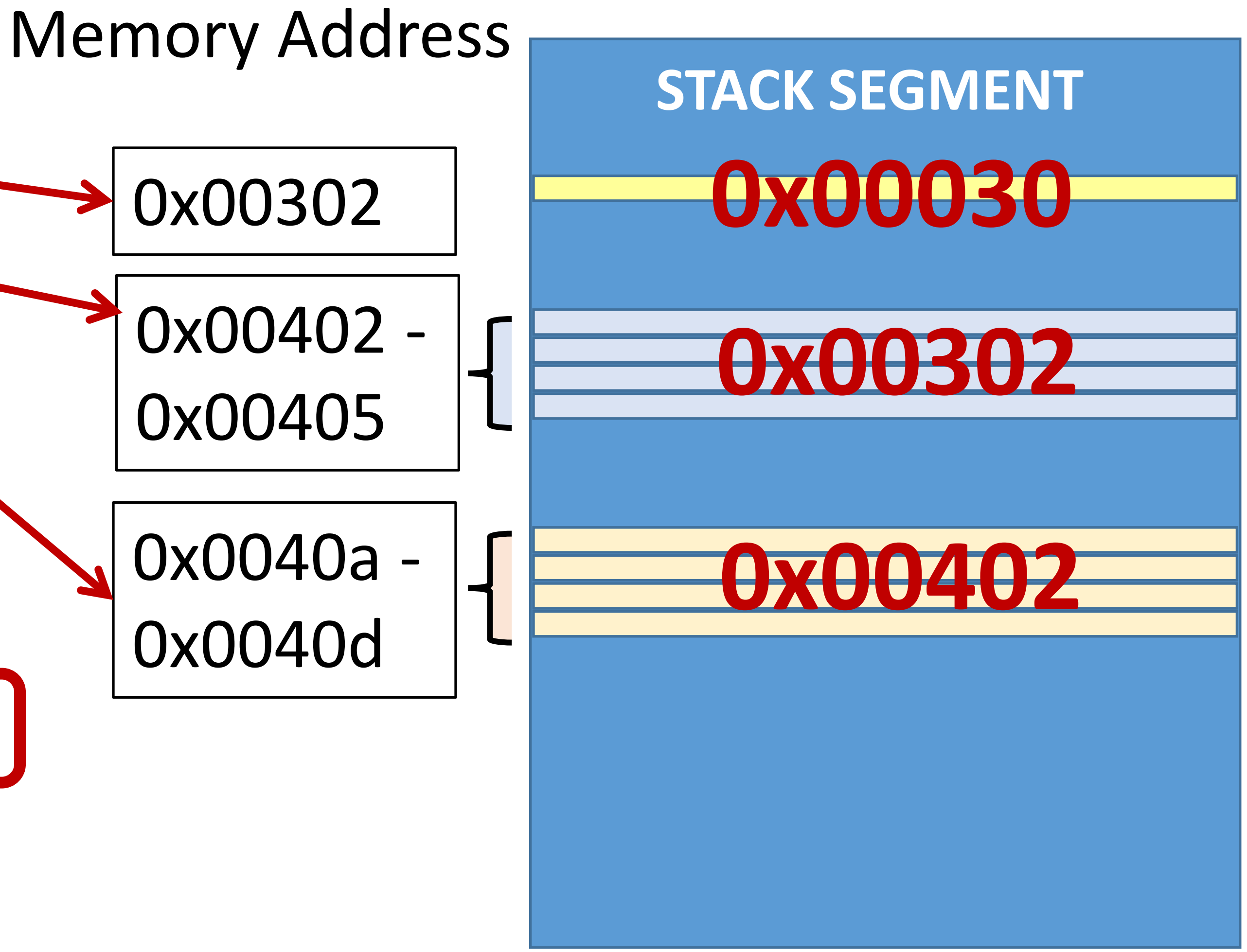
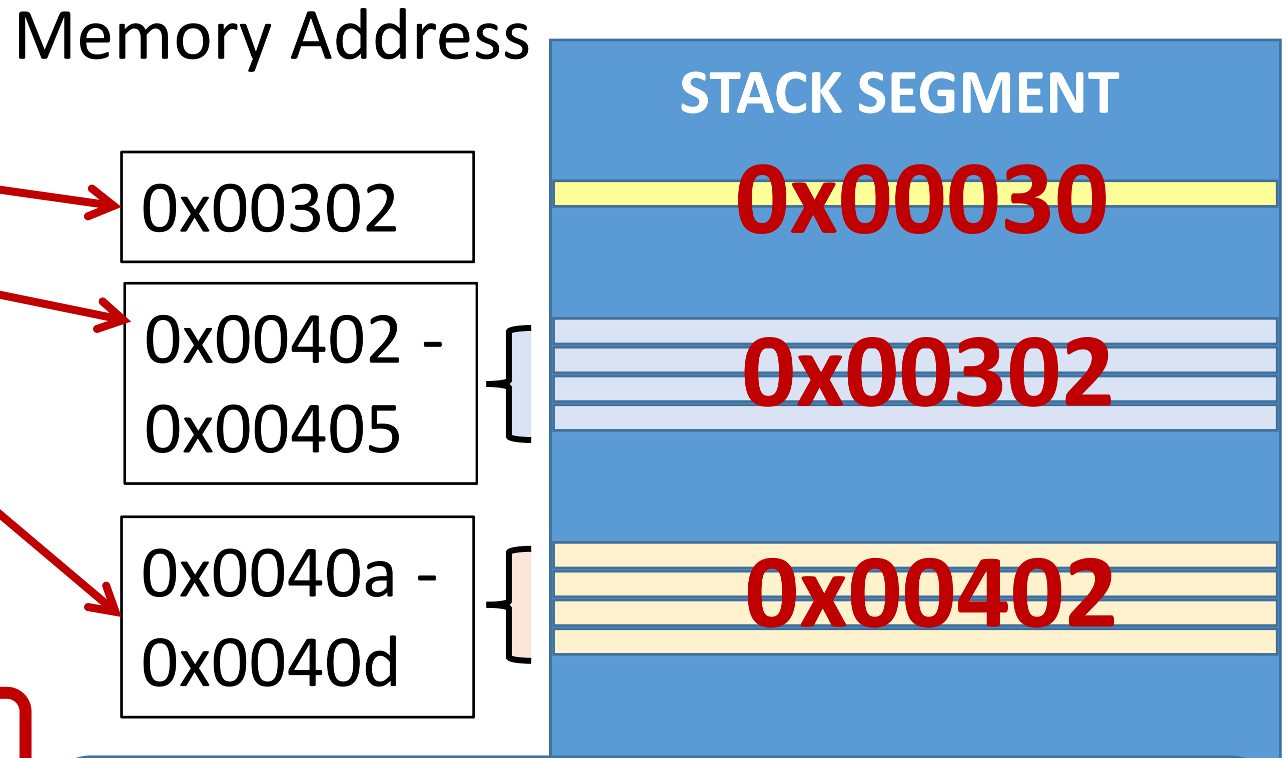
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



# Can We Have Dereferences of Dereferences?

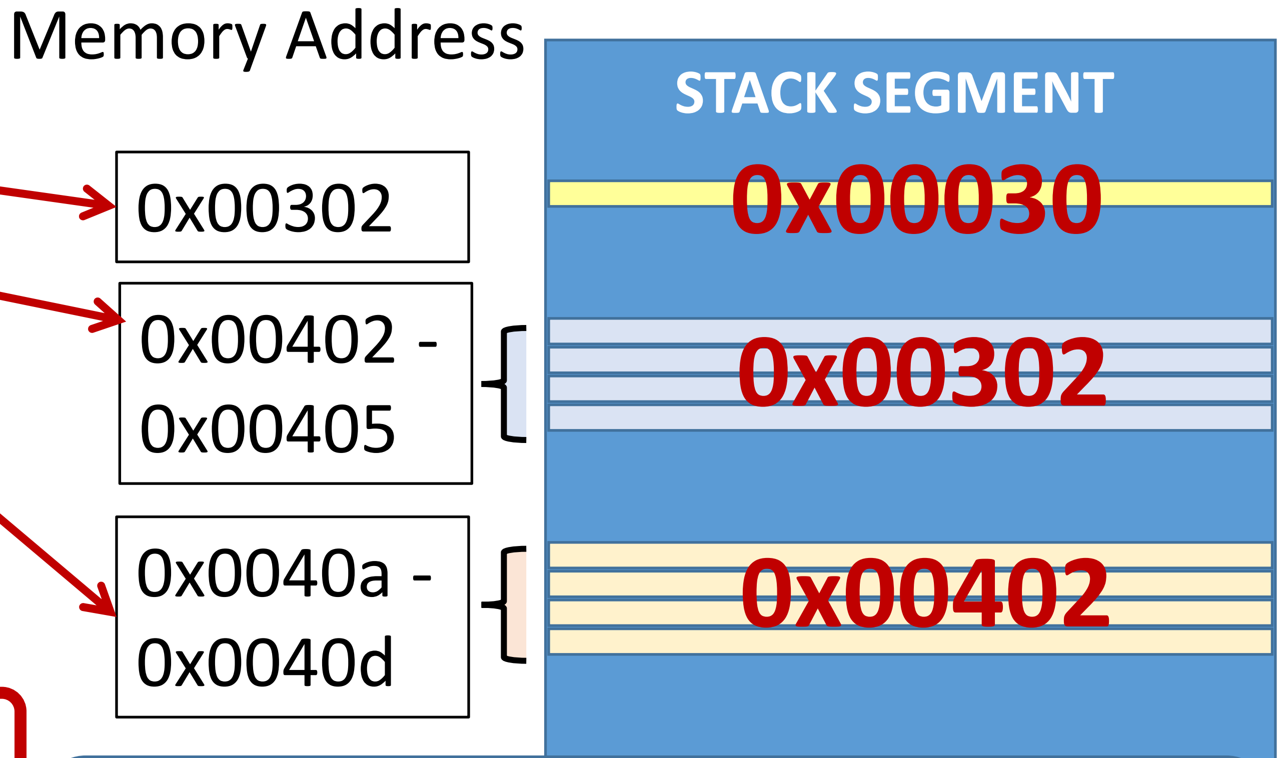
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



**What is the value of *ptrPtrC ?**

# Can We Have Dereferences of Dereferences?

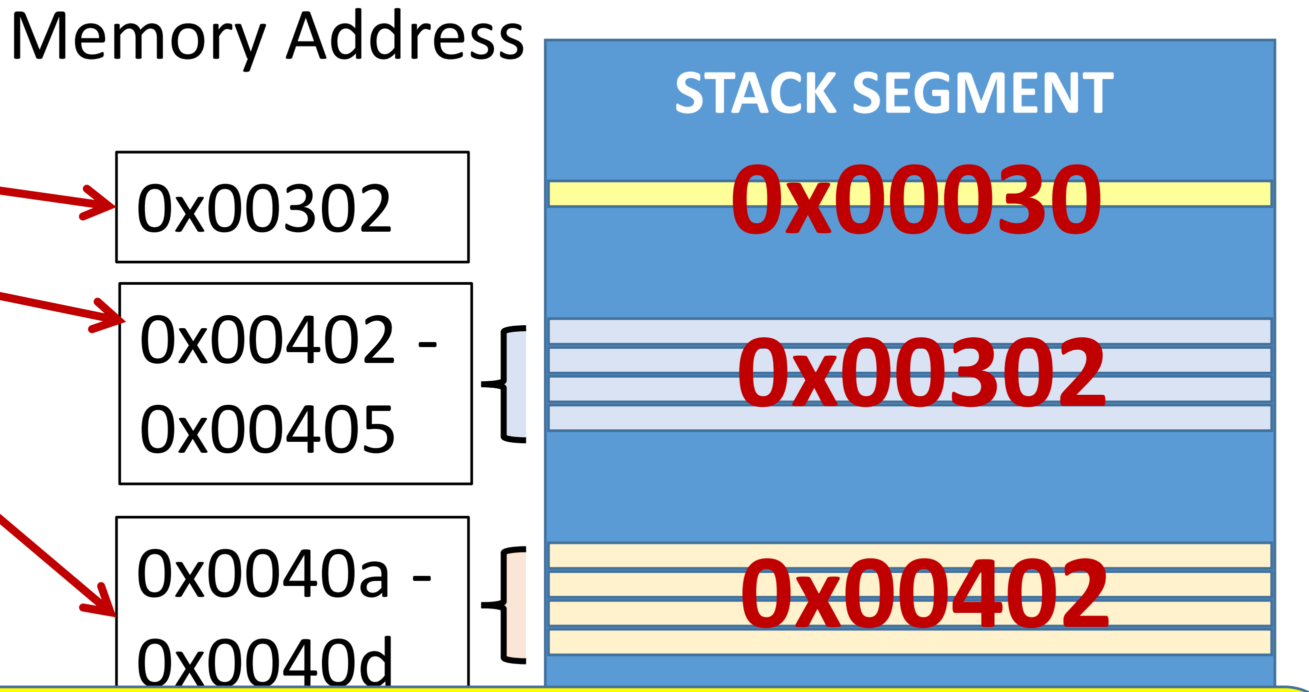
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



**ptrPtrC has value 0x00402**

# Can We Have Dereferences of Dereferences?

```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*p
  return 0;
}
```



Memory Address

0x00302

0x00402 - 0x00405

0x0040a - 0x0040d

STACK SEGMENT

0x00030

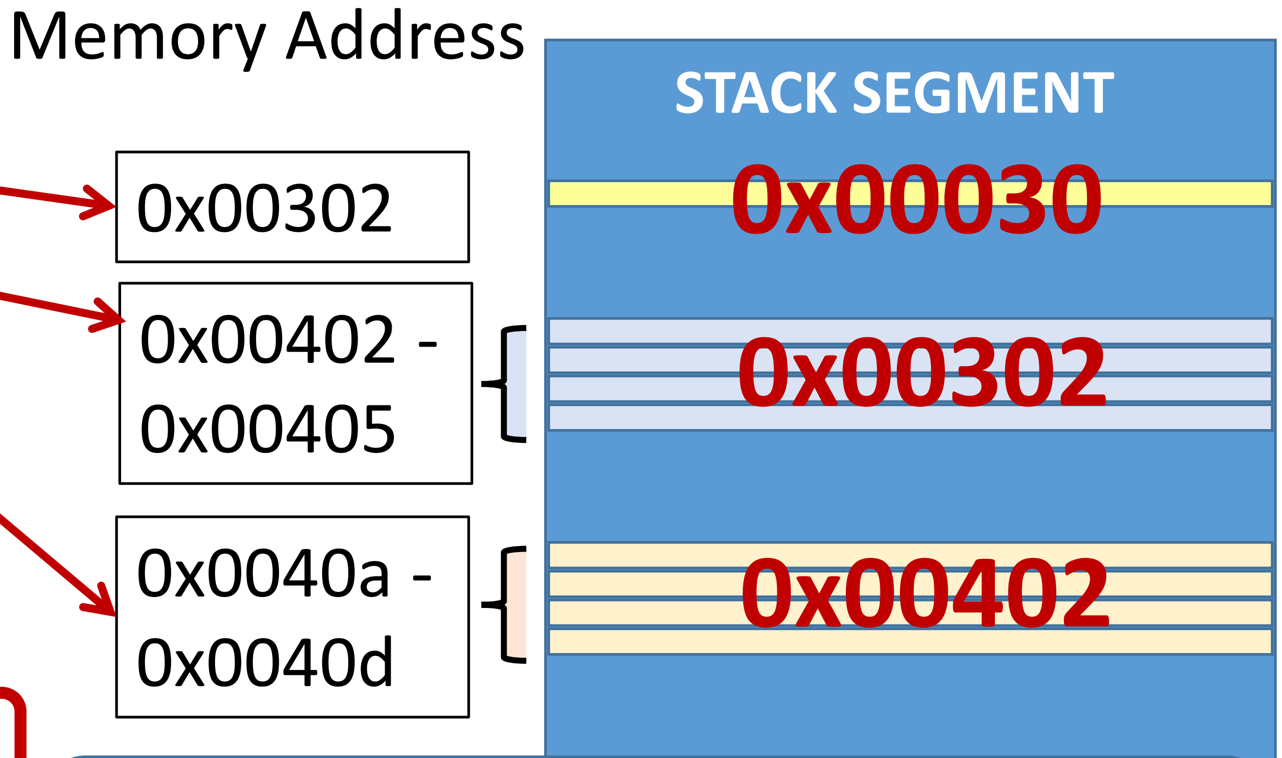
0x00302

0x00402

***ptrPtrC has value**
**“content of memory at address 0x00402”**

# Can We Have Dereferences of Dereferences?

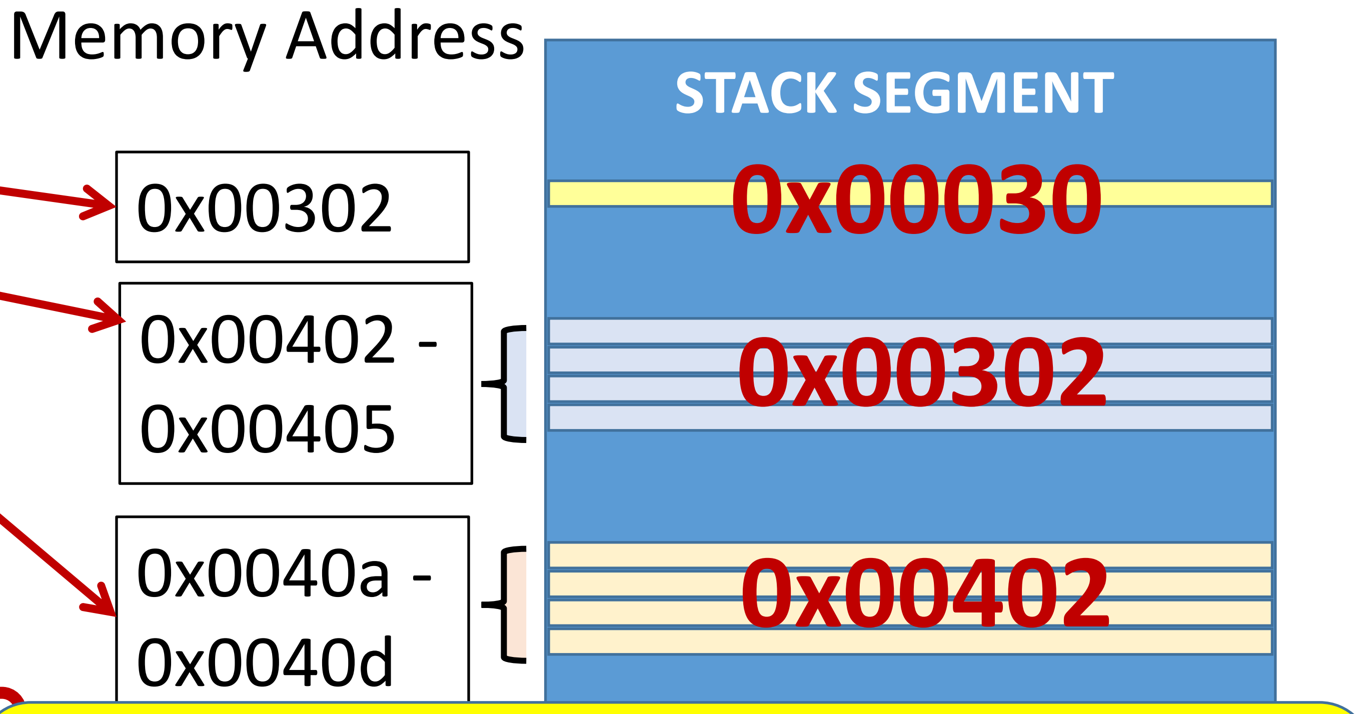
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



**Content at address 0x00402:**
**How many bytes to read?**

# Can We Have Dereferences of Dereferences?

```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



Memory Address

0x00302

0x00402 -
0x00405

0x0040a -
0x0040d

STACK SEGMENT

0x00030

0x00302

0x00402

**How many bytes to read?**

**ptrPtrC is pointer to what data type?**

**pointer (4 bytes)**

# Can We Have Dereferences of Dereferences?

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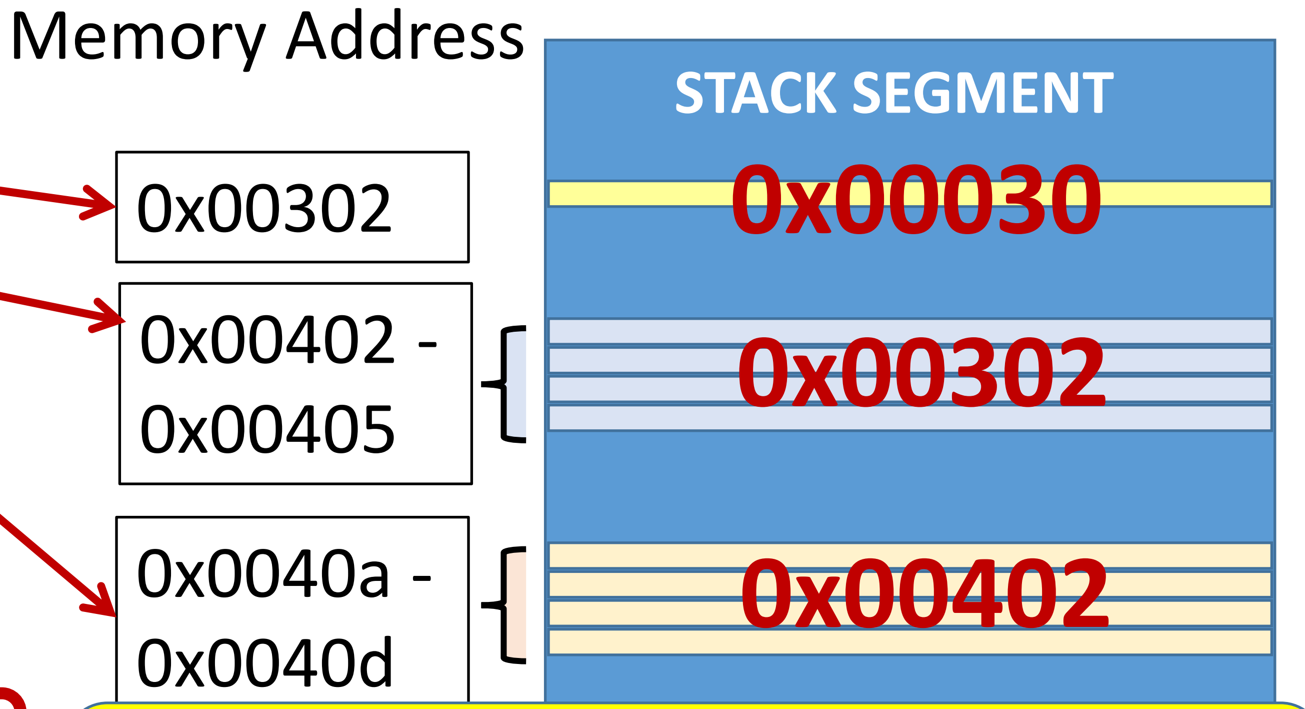
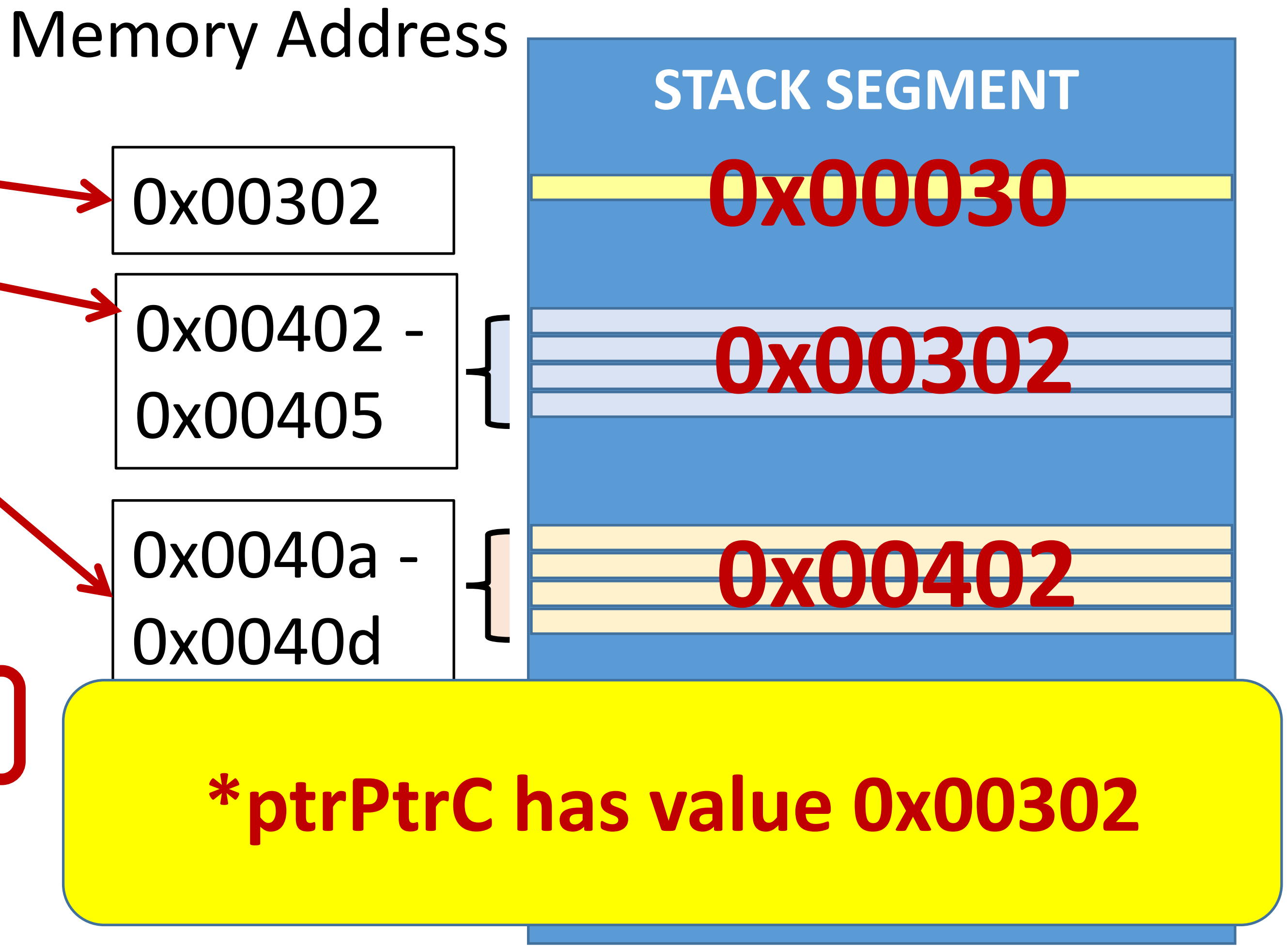
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



**To get *ptrPtrC, read 4 bytes starting from address 0x00402**

# Can We Have Dereferences of Dereferences?

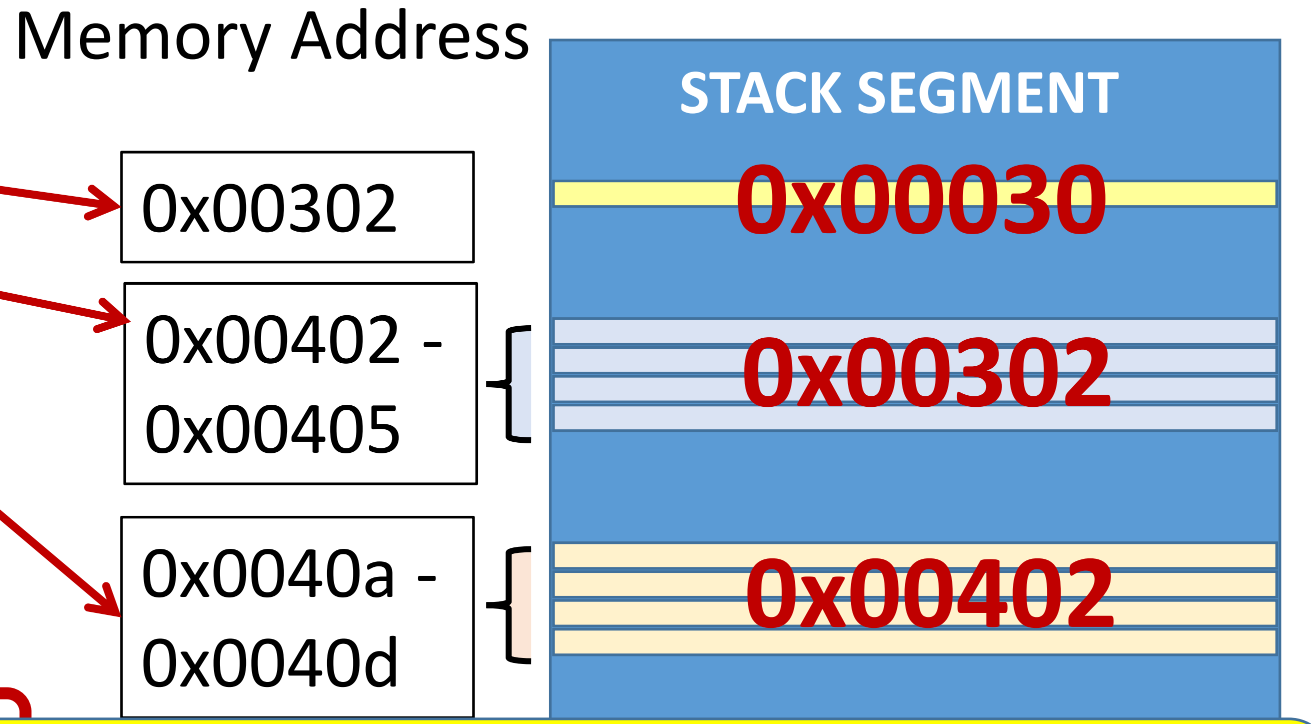
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



*ptrPtrC has value 0x00302

# Can We Have Dereferences of Dereferences?

```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*
  return 0;
}
```



**What is * (*ptrPtrC) ?**

**“content of memory at address 0x00302”**

# Can We Have Dereferences of Dereferences?

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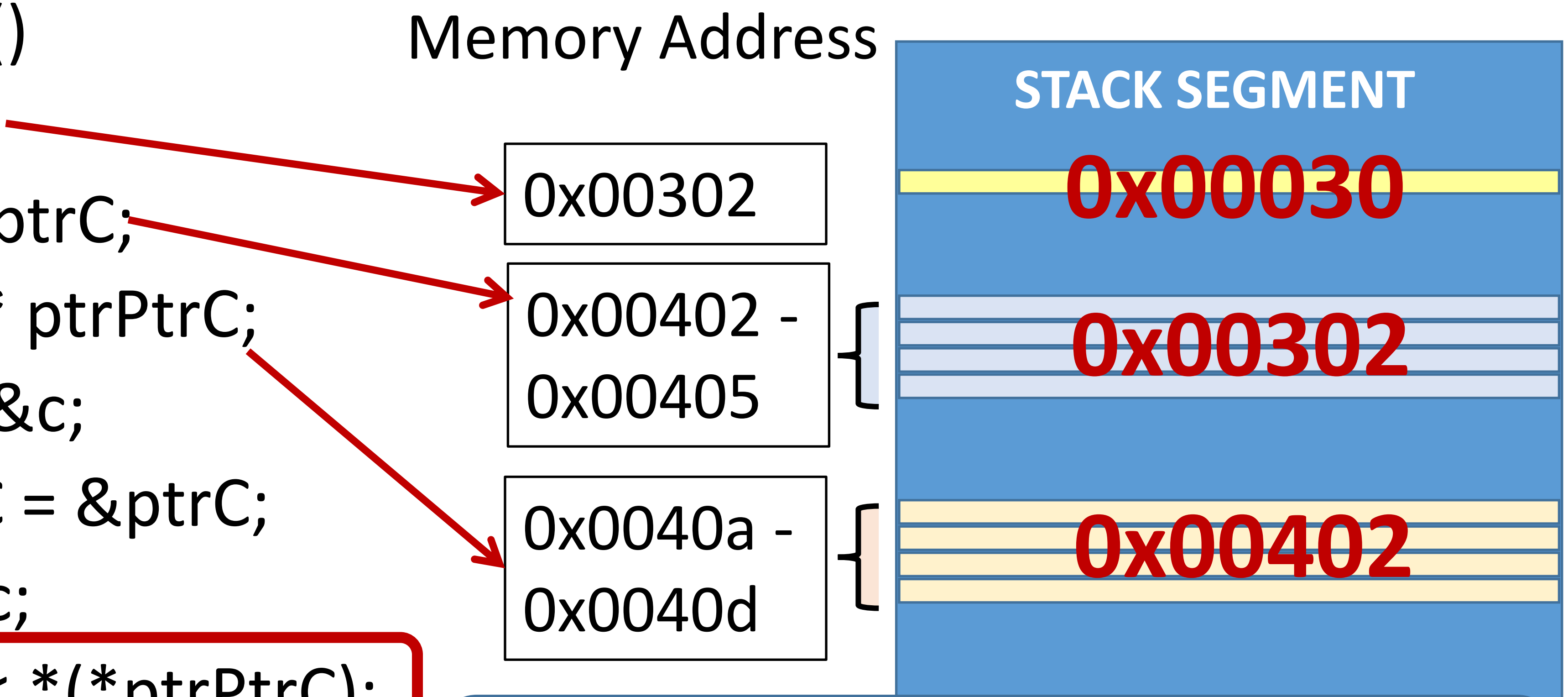
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



Memory Address

0x00302

0x00402 -
0x00405

0x0040a -
0x0040d

STACK SEGMENT

0x00030

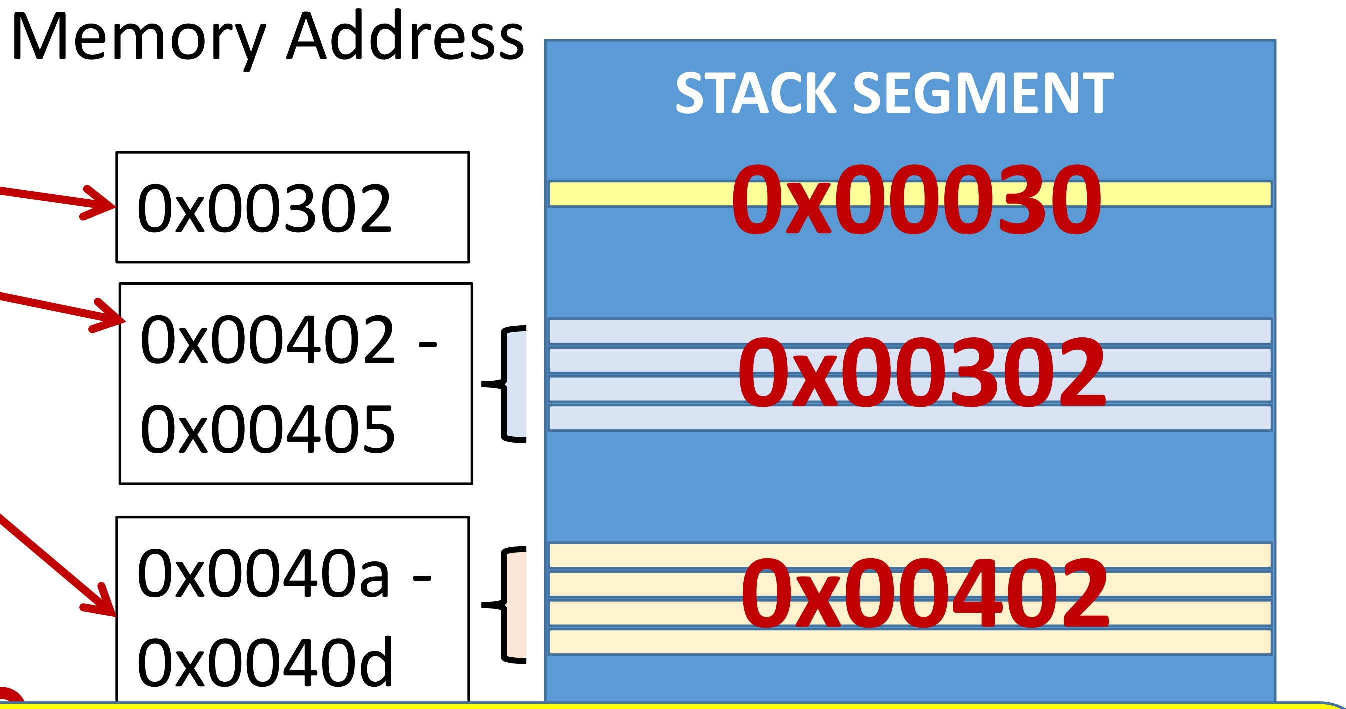
0x00302

0x00402

**Content at address 0x00302:**
**How many bytes to read?**

# Can We Have Dereferences of Dereferences?

```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC)
  return 0;
}
```



**How many bytes to read?**

***ptrPtrC is pointer to what data type?**

**char (1 byte)**

# Can We Have Dereferences of Dereferences?

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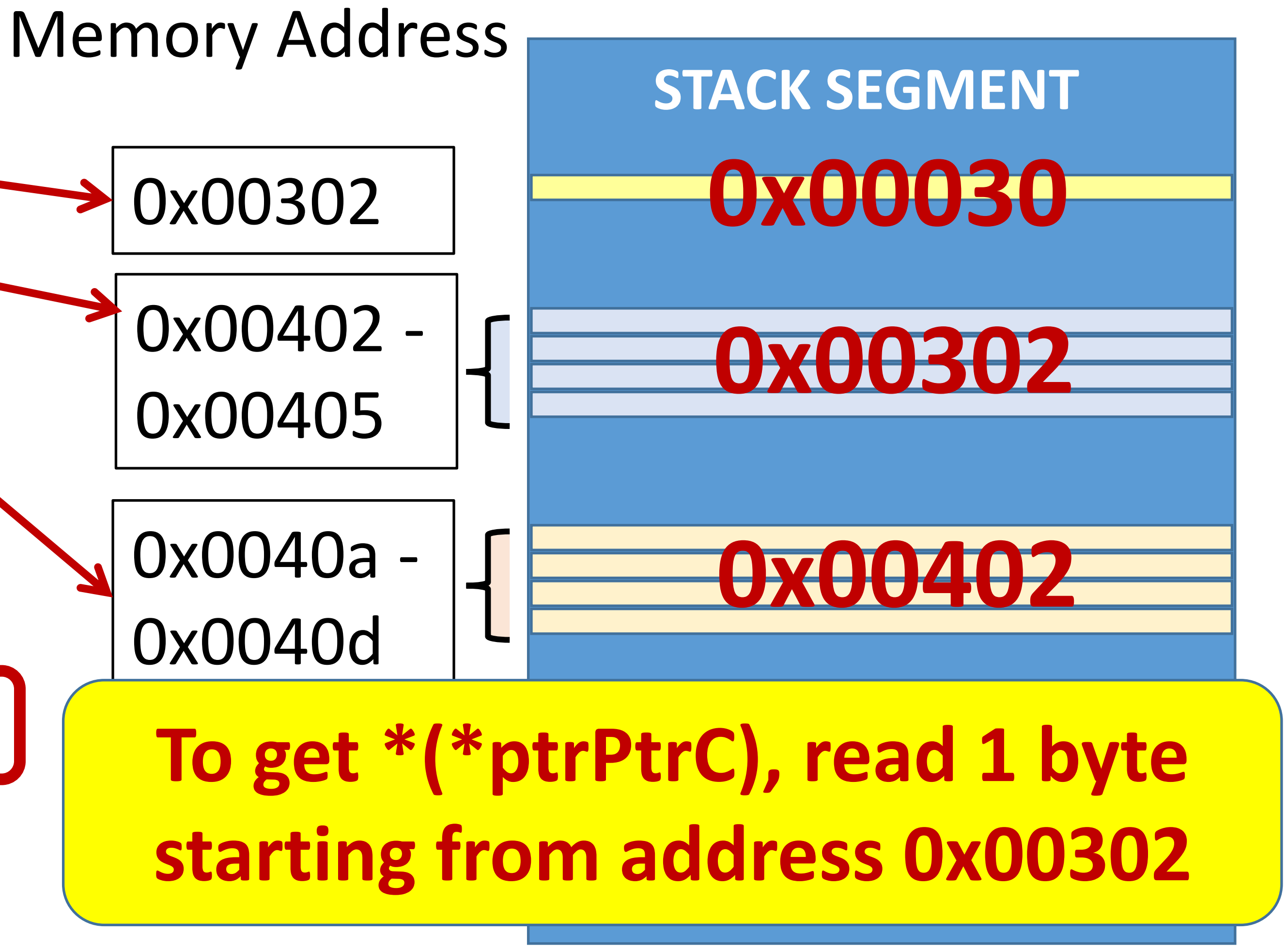
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



**To get *(*ptrPtrC), read 1 byte starting from address 0x00302**

# Can We Have Dereferences of Dereferences?

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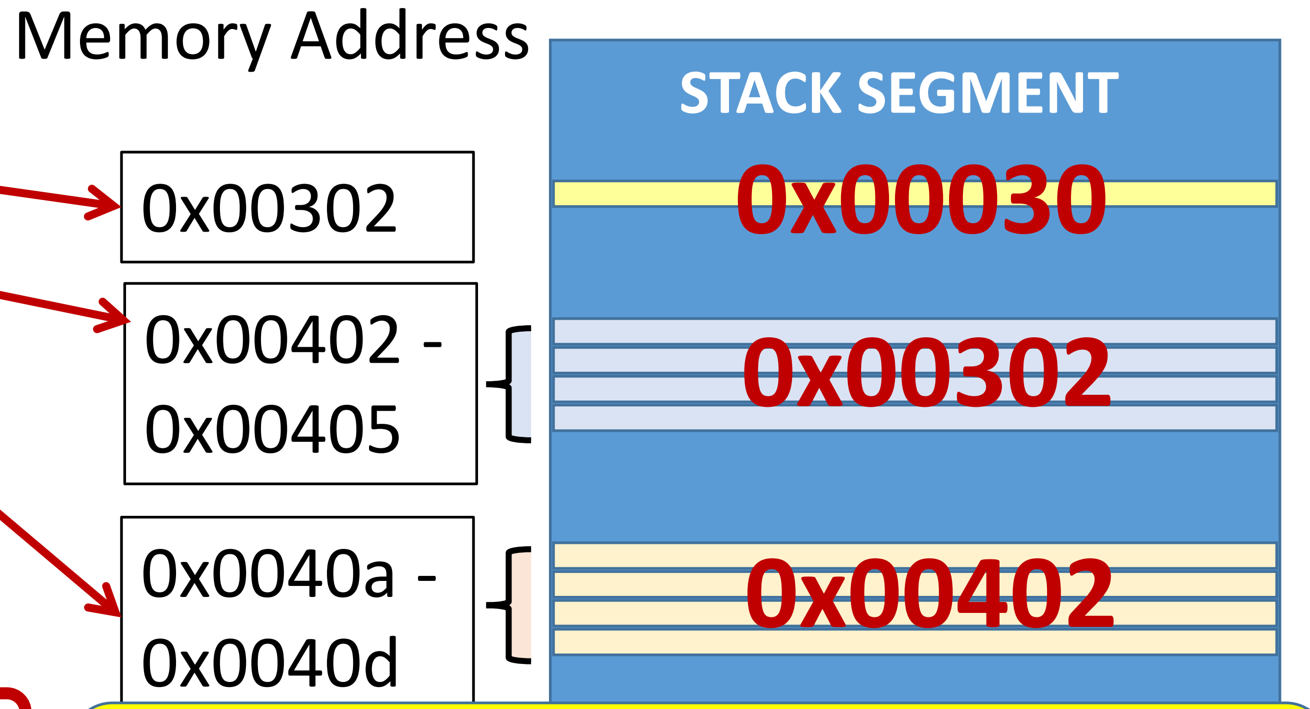
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



***(*ptrPtrC) has value 0x00030**

# How Far Can We Nest Dereferences?

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- No pre-specified limit
- If **x** is a variable of type **int ******, we can use upto four levels of dereferencing of **x**
  - Declaration: **int **** x;**
  - ***x**: expression of type **int ***** [Think **int ***** ***x**;]
  - ***(*x)**: expression of type **int **** [Think **int **** ****x**;]
  - ***(*(*x))**: expression of type **int *** [Think **int *** *****x**;]
  - ***(*(*(*x)))**: expression of type **int** [Think **int** ******x**;]
  - ***(*(*(*(*x)))): Compilation error, since *(*(*(*x))) is not of pointer type, and cannot be dereferences**

# Caveats When Dereferencing

- Certain memory addresses outside the part of memory allocated to process by operating system
- Dereferencing such an address leads to runtime error
    - Segmentation violation
    - Program aborts/crashes
- Memory location with address 0x0 is never within any user process' memory space
    - Dereferencing 0x0 will certainly cause program to crash
- Need to be careful that we are dereferencing addresses of memory locations allocated to process

# Summary

- Dereferencing a memory address
  - Finding content at given address
- “Content of” operator in C++
- Caveats when using “content of” operator
  - Deferencing “bad” addresses
- We can now access memory locations through their addresses