Computer Programming

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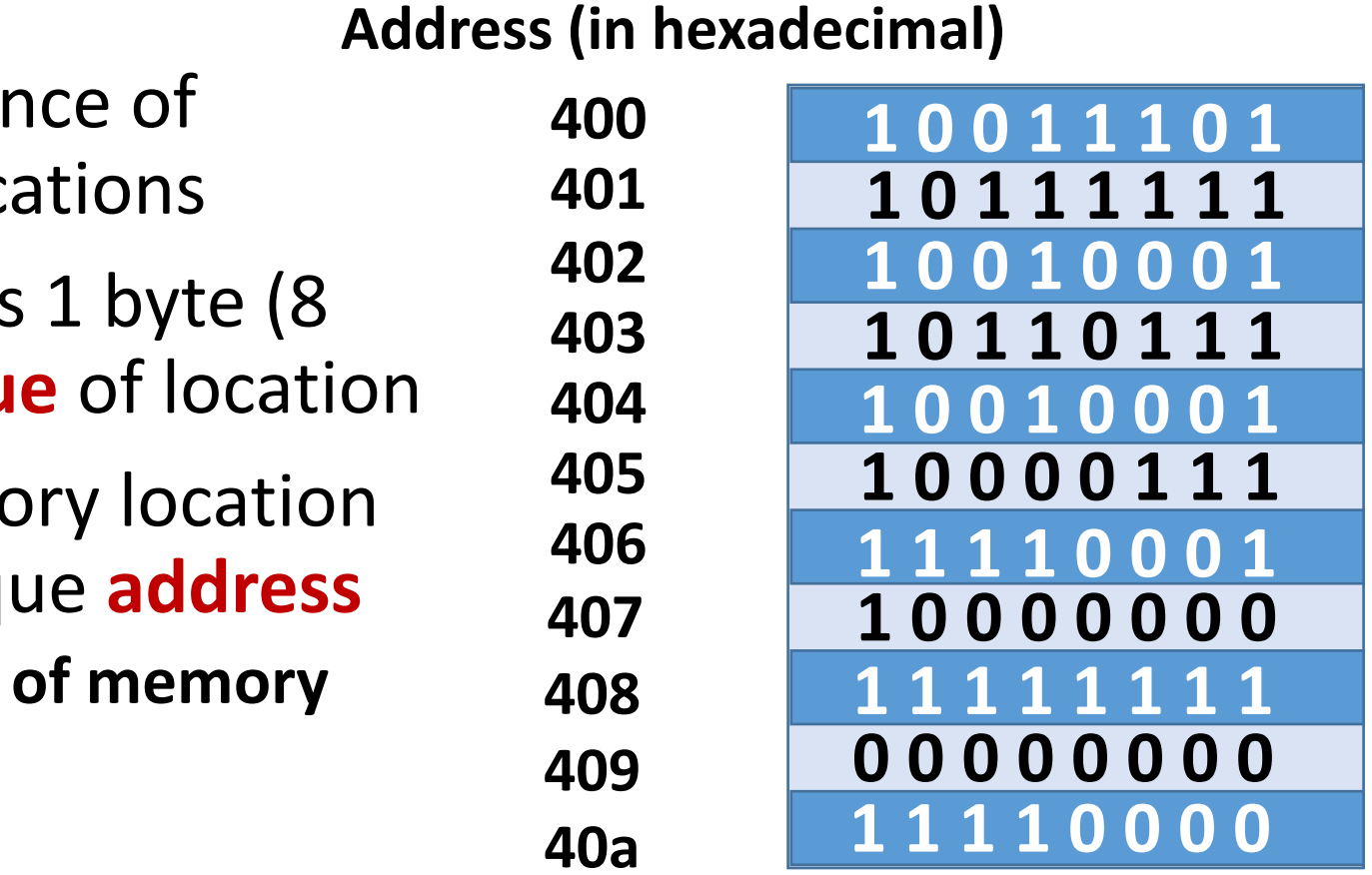
- Memory is a sequence of physical storage locations
- Each location stores 1 byte (8 bits): **Content/value** of location
- Each physical memory location identified by a unique **address**
  - **Index in sequence of memory locations**



Memory For Executing A Program (Process)

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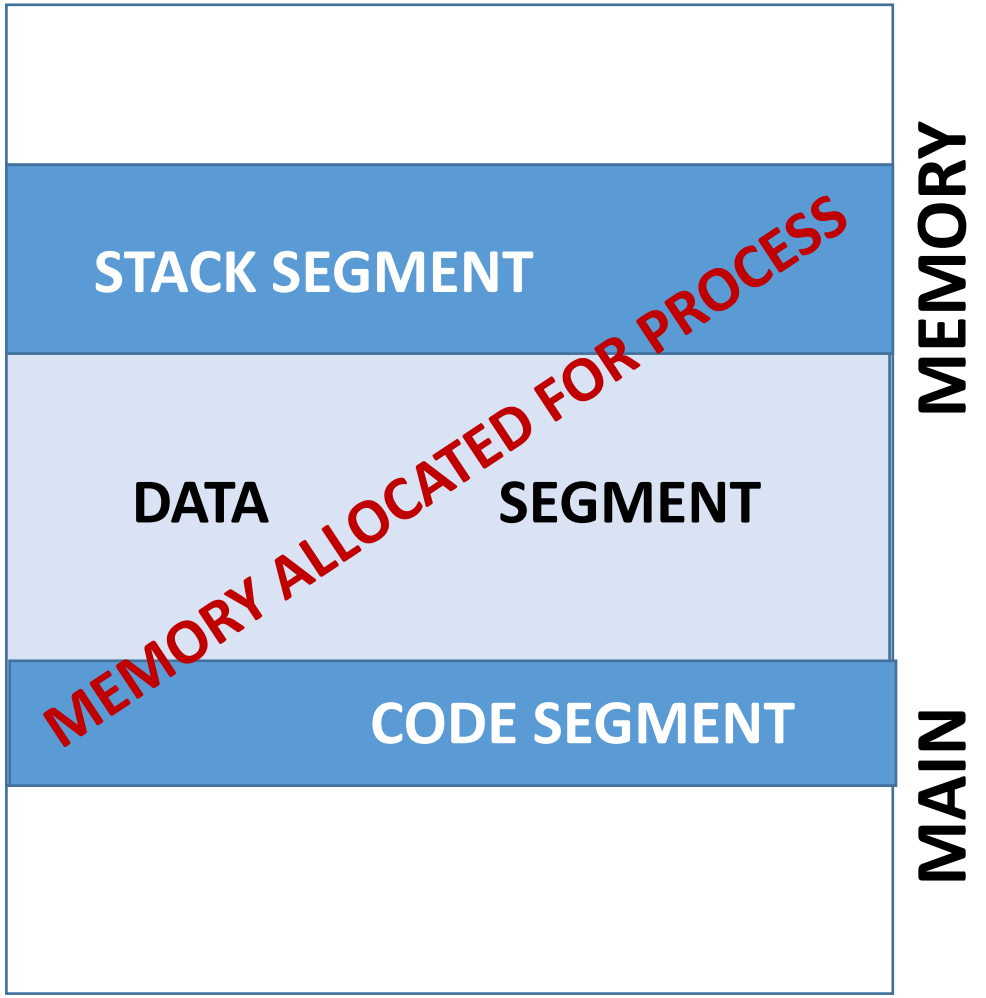
- Operating system allocates a part of main memory for use by a process
- Divided into:

  Code segment: Stores executable instructions in program

  Data segment: For dynamically allocated data (later lecture)

  Stack segment: Call stack



Accessing Content At Given Address

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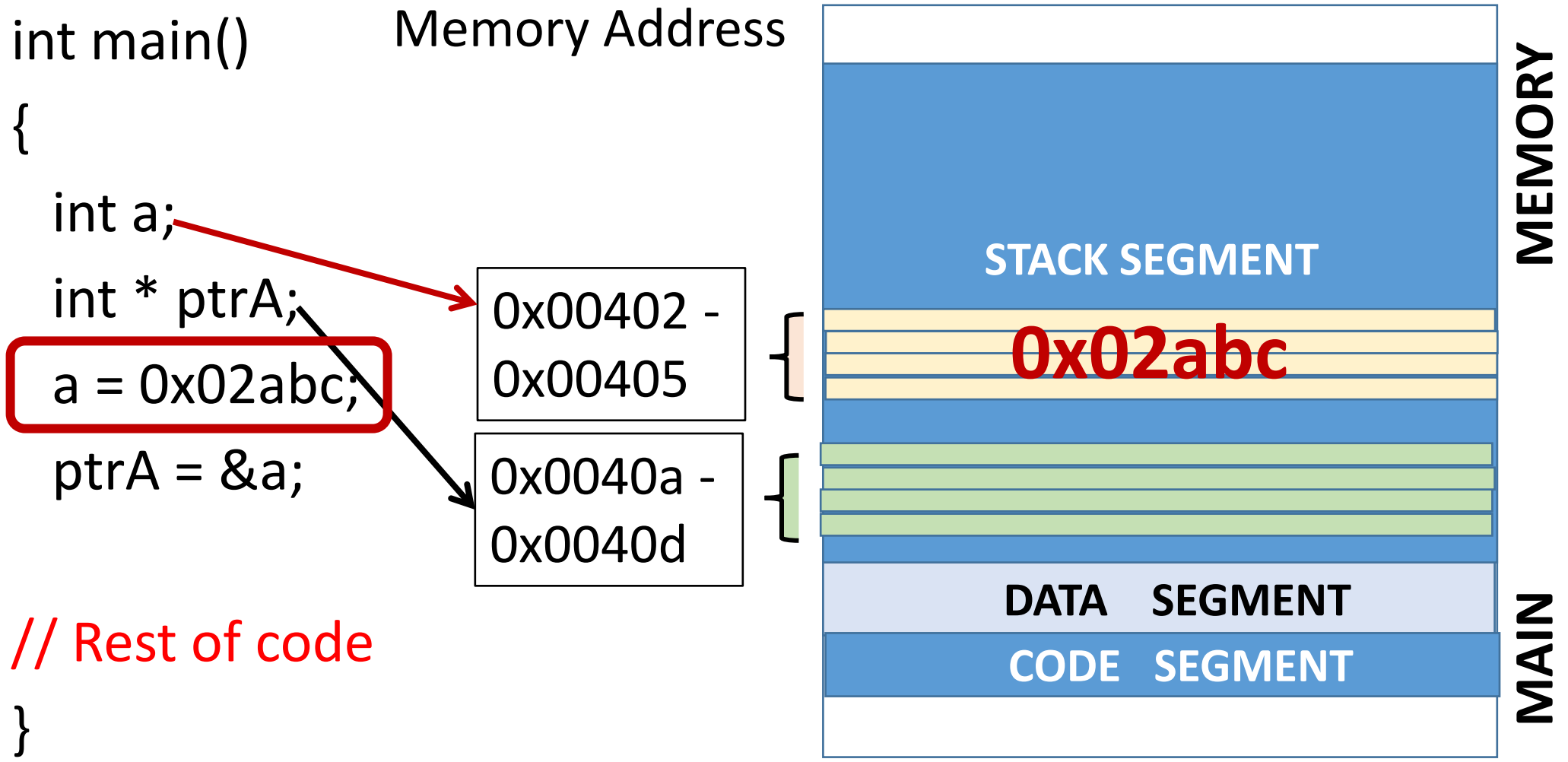
```
int main()
{
   int a;
   int * ptrA;
   a = 0x02abc;
   ptrA = &a;

// Rest of code
}
```

Memory Address



Accessing Content At Given Address

IIT Bombay

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// Rest of code
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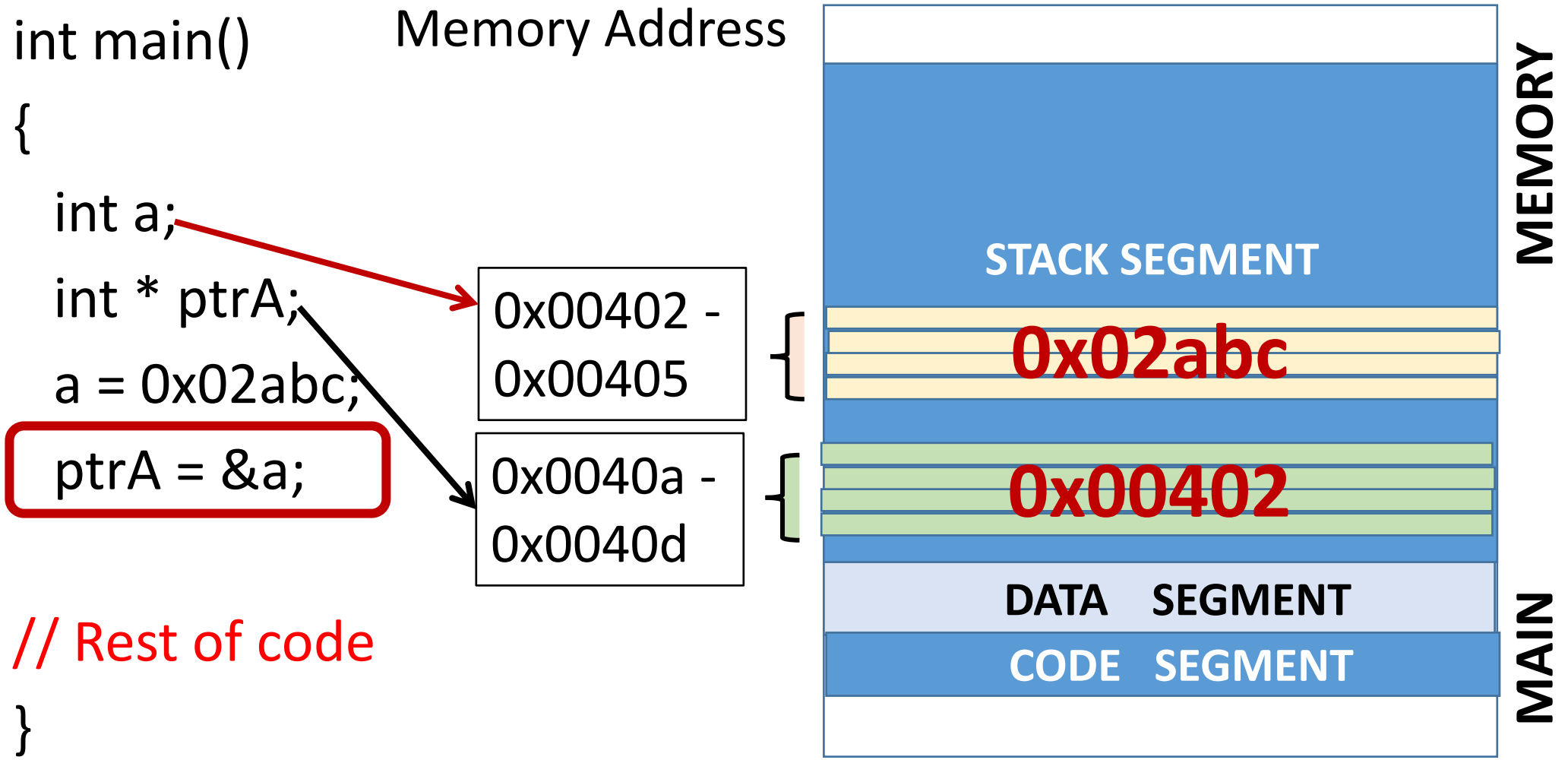
```



Accessing Content At Given Address

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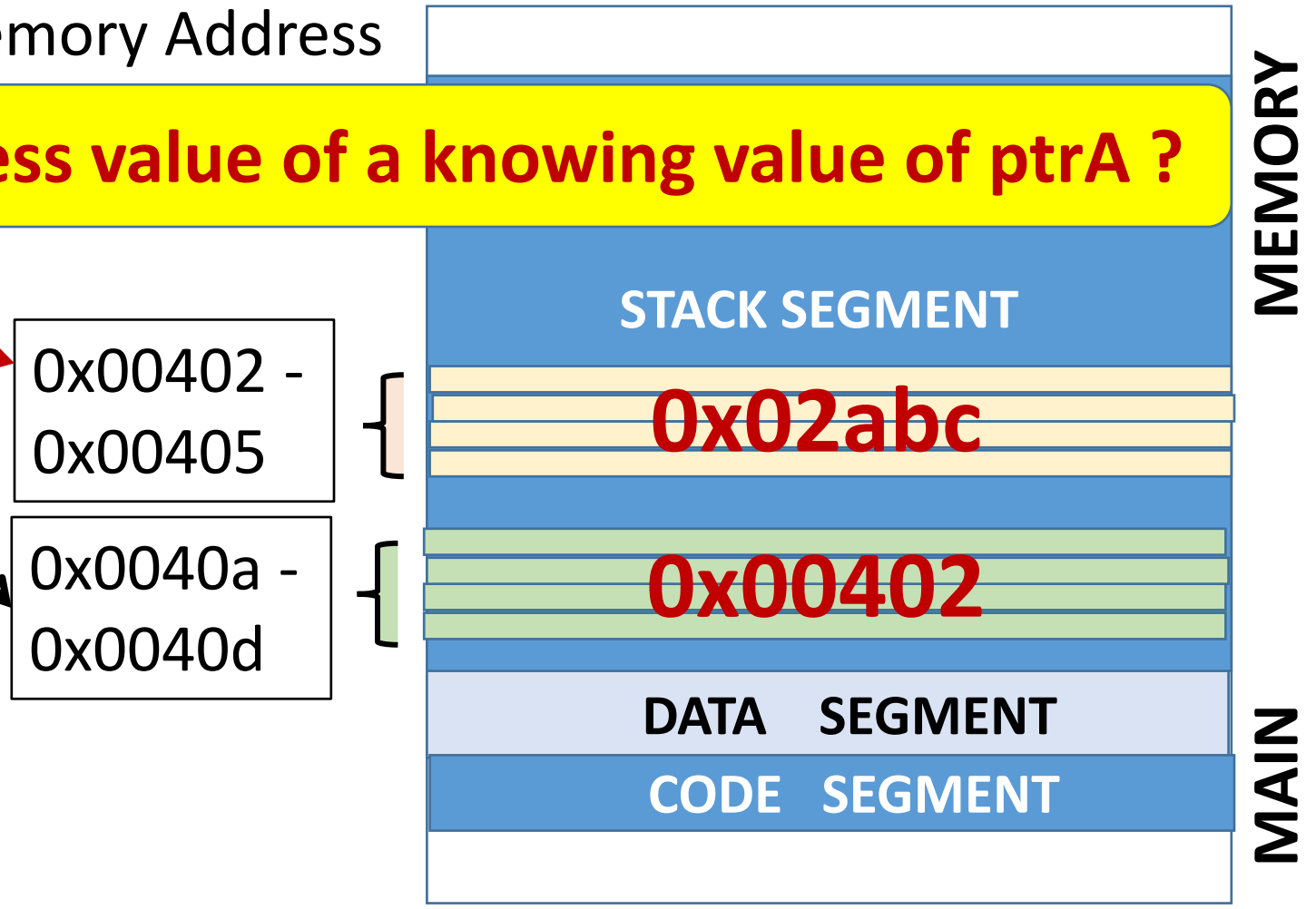
```
int main()
{
   int a;
   int * ptrA;
   a = 0x02abc;
   ptrA = &a;

// Rest of code
}
```

Memory Address

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

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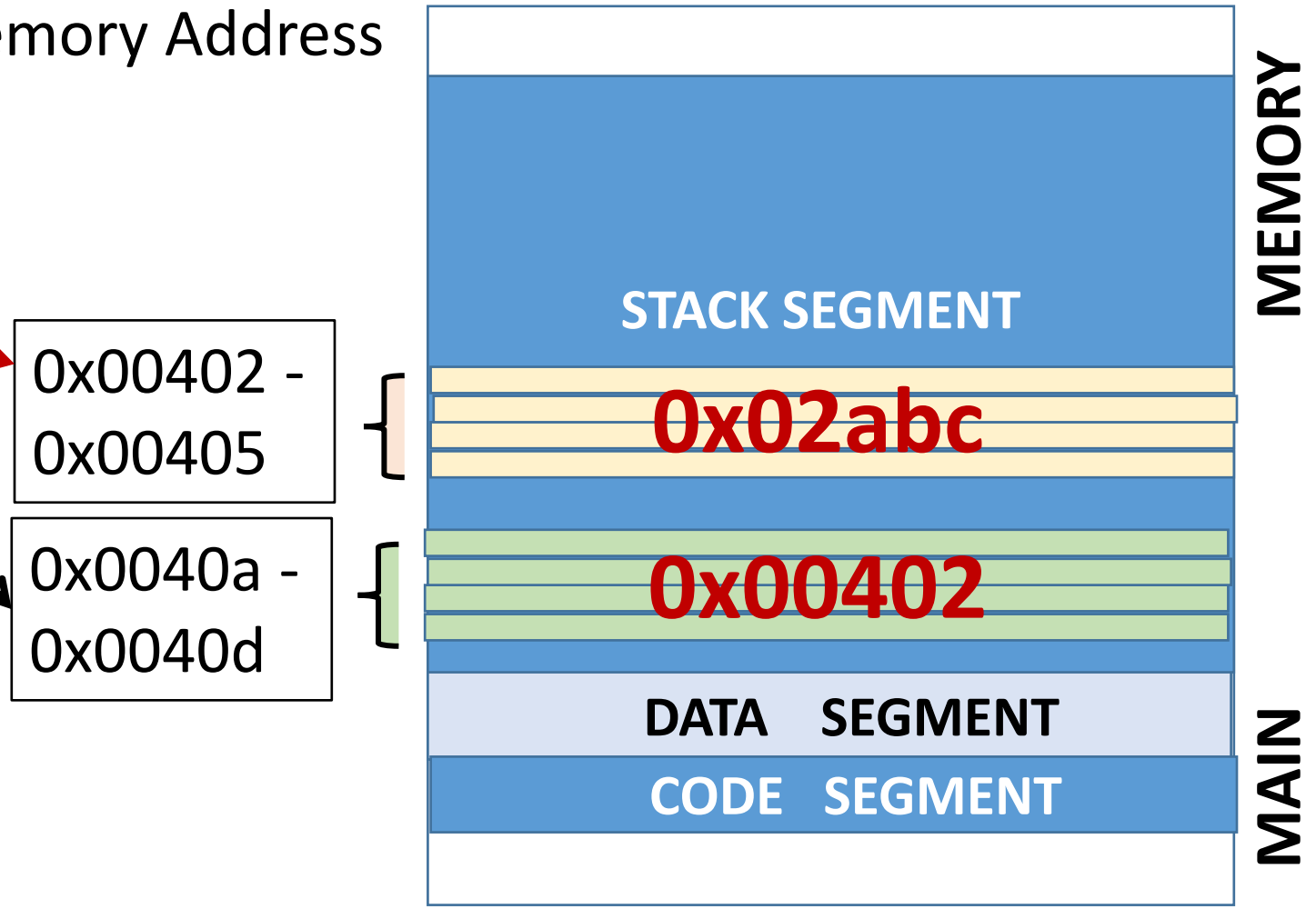
```
int main()
{
   int a;
   int * ptrA;
   a = 0x02abc;
   ptrA = &a;
   cout << *ptrA;
// Rest of code
}
```



Accessing Content At Given Address

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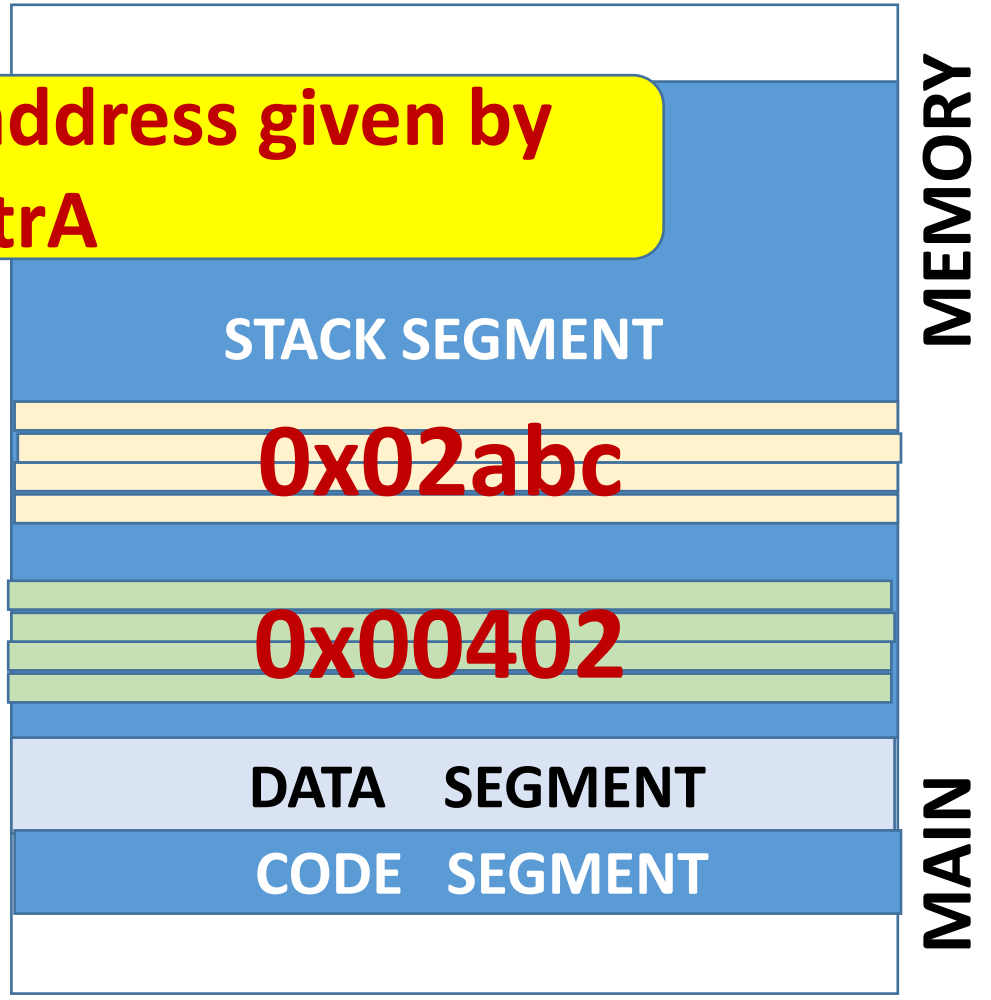
```
int main()
{
   int a;
   int * ptrA
   a = 0x02
   ptrA = &a;
   cout << *ptrA;
// Rest of code
}
```

Memory Address

Find content/value at address given by value of ptrA

0x00402 - 0x00405

0x0040a - 0x0040d



Accessing Content At Given Address

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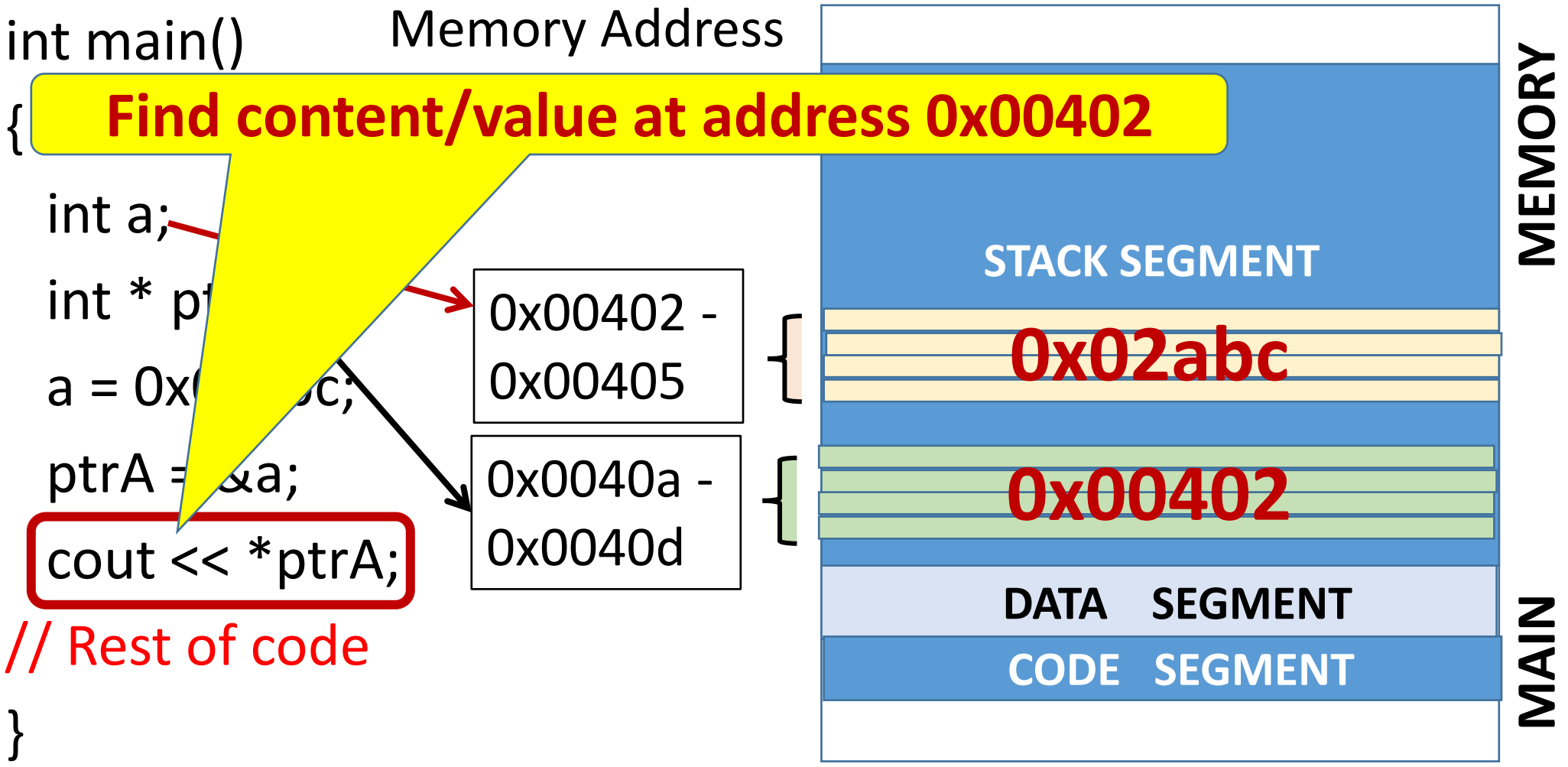

Accessing Content At Given Address

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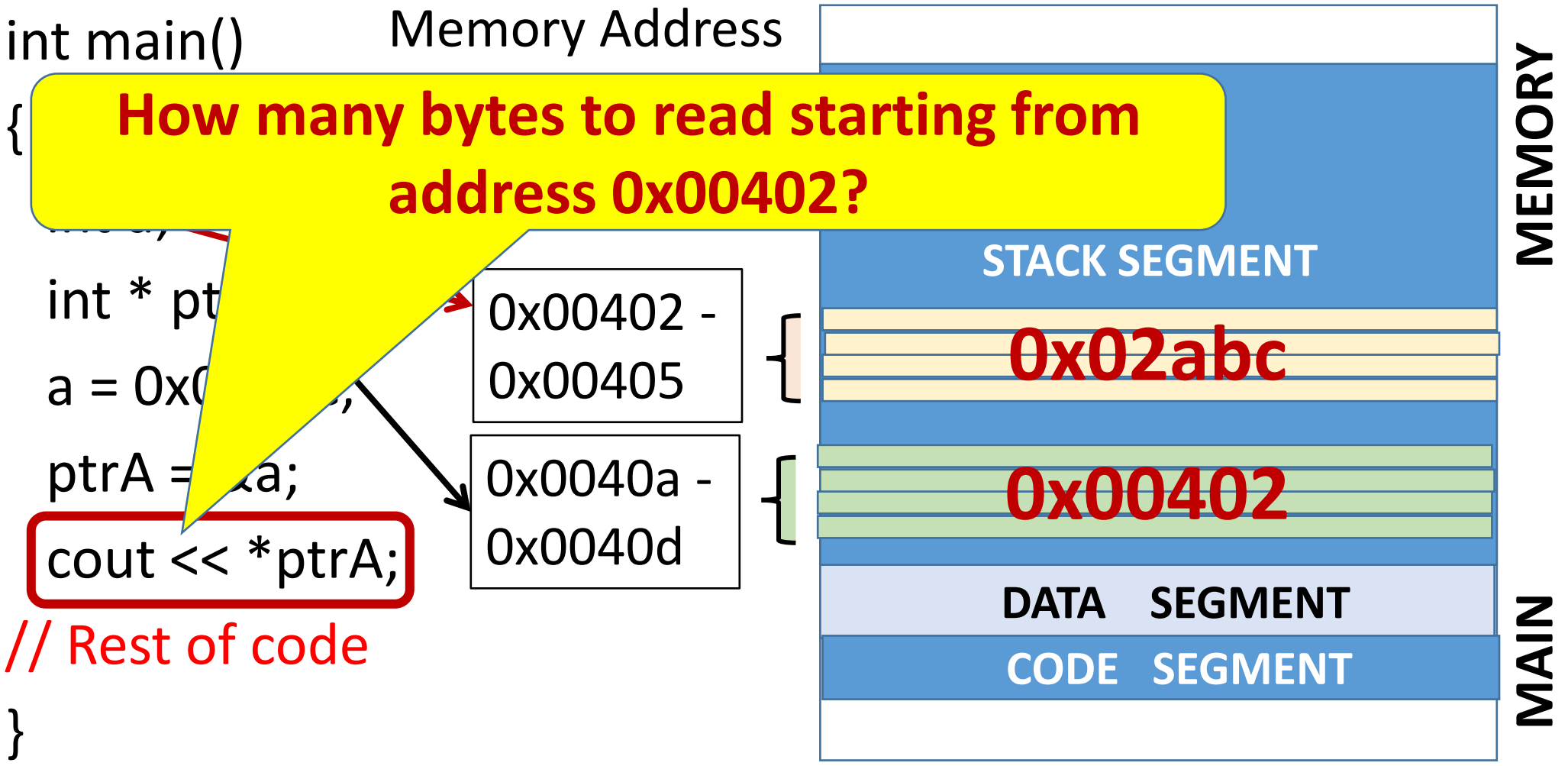

Accessing Content At Given Address

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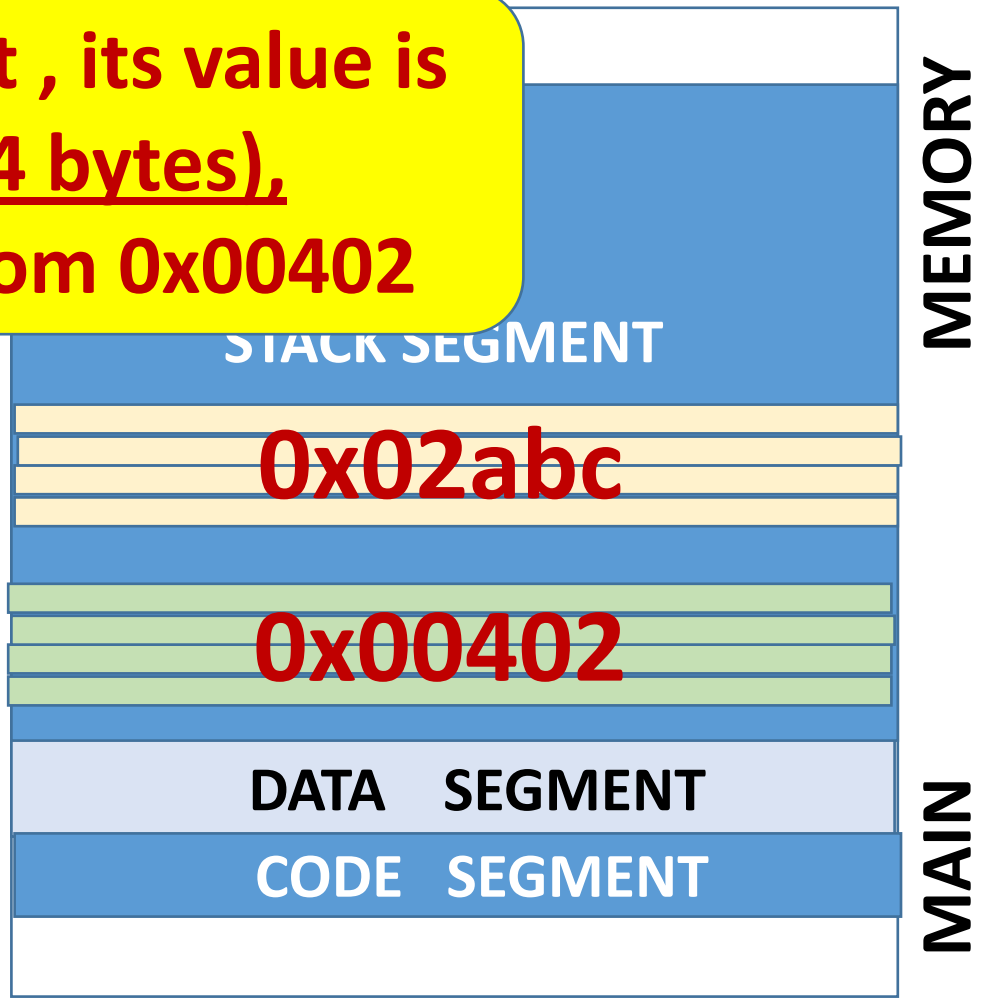
Since ptrA is a pointer to int , its value is address of an integer (4 bytes), so read 4 bytes starting from 0x00402

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

0x00402 - 0x00405

0x0040a - 0x0040d



Accessing Content At Given Address

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```
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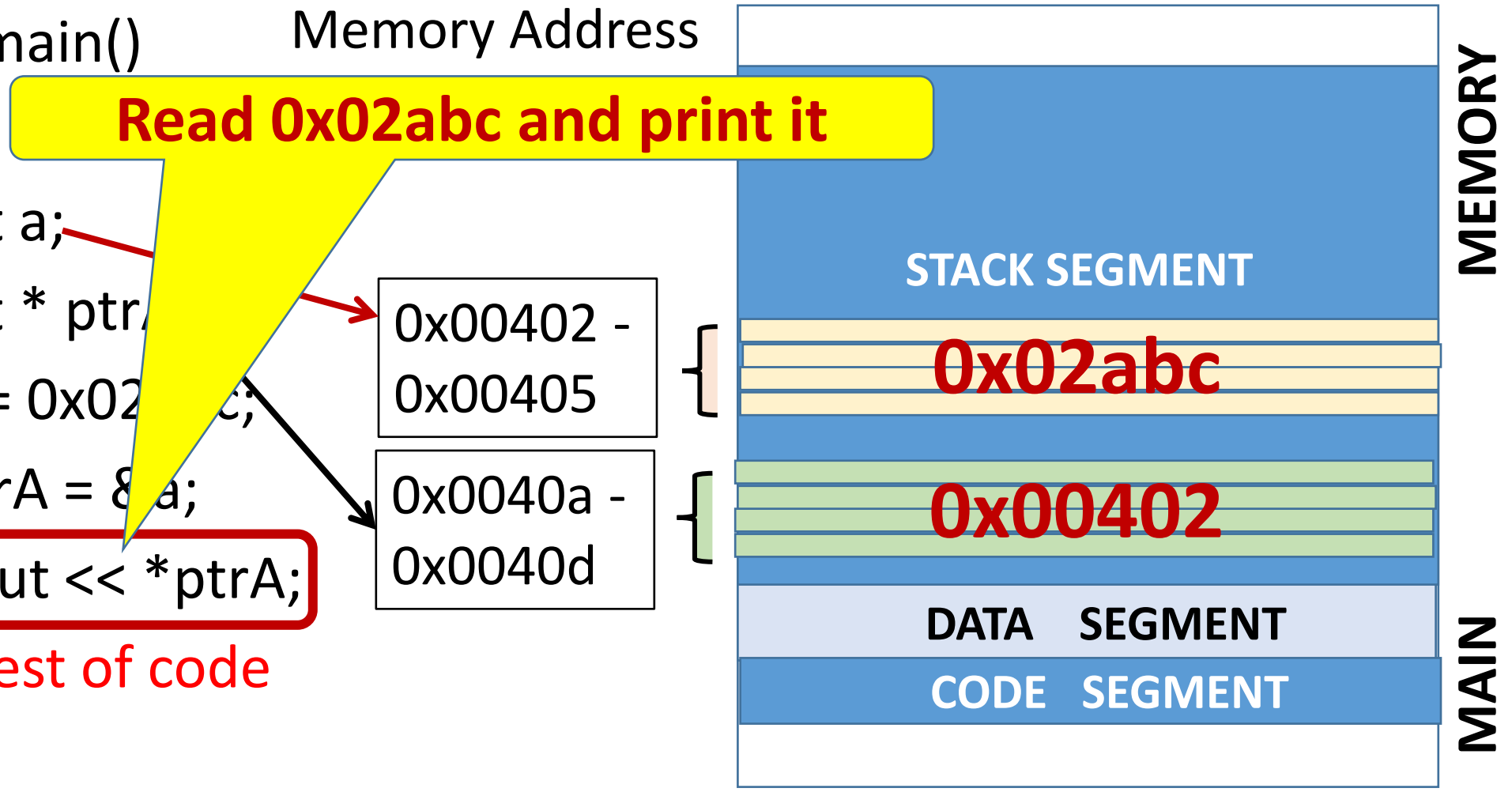

Accessing Content At Given Address

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- 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?

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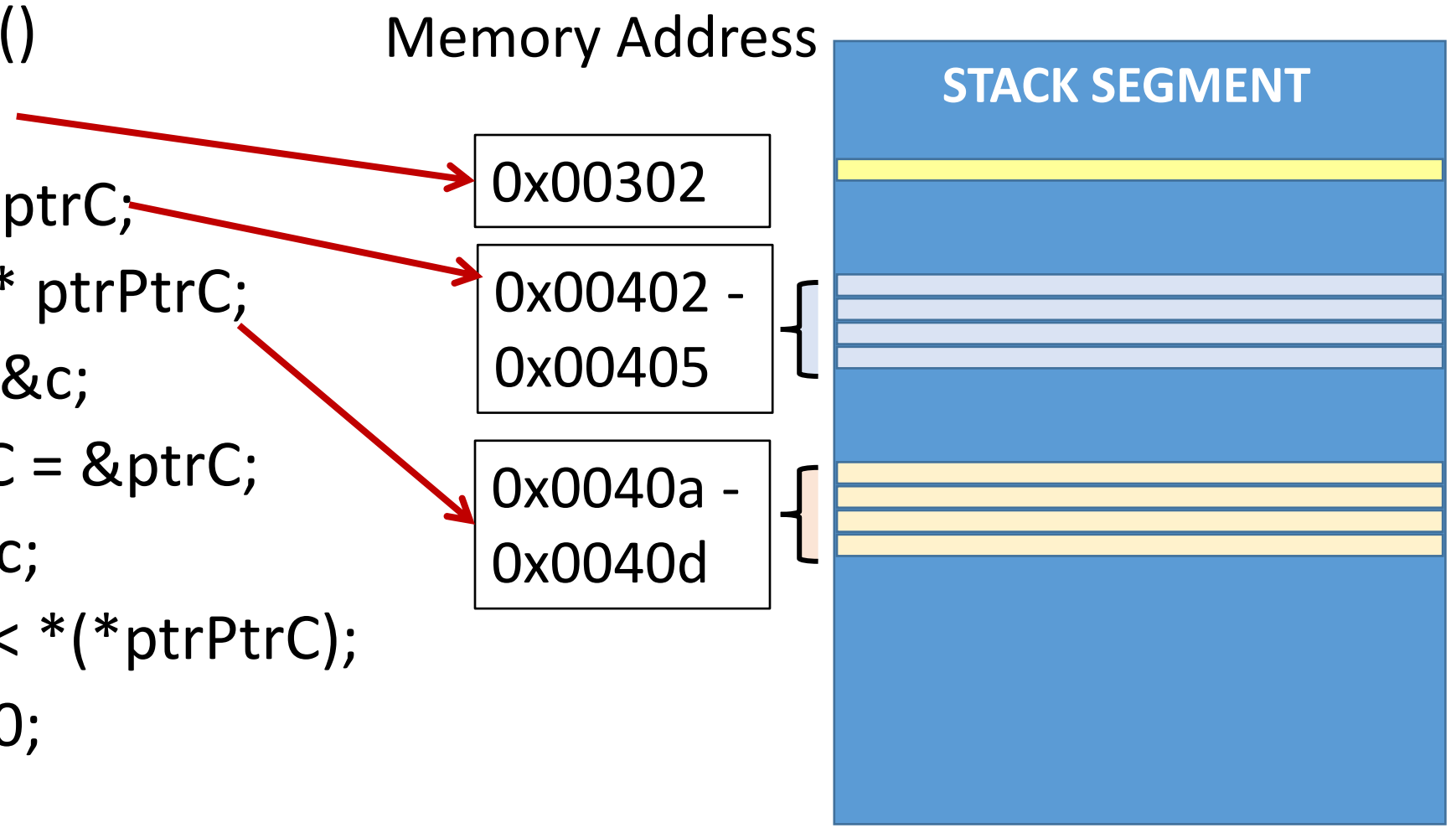
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



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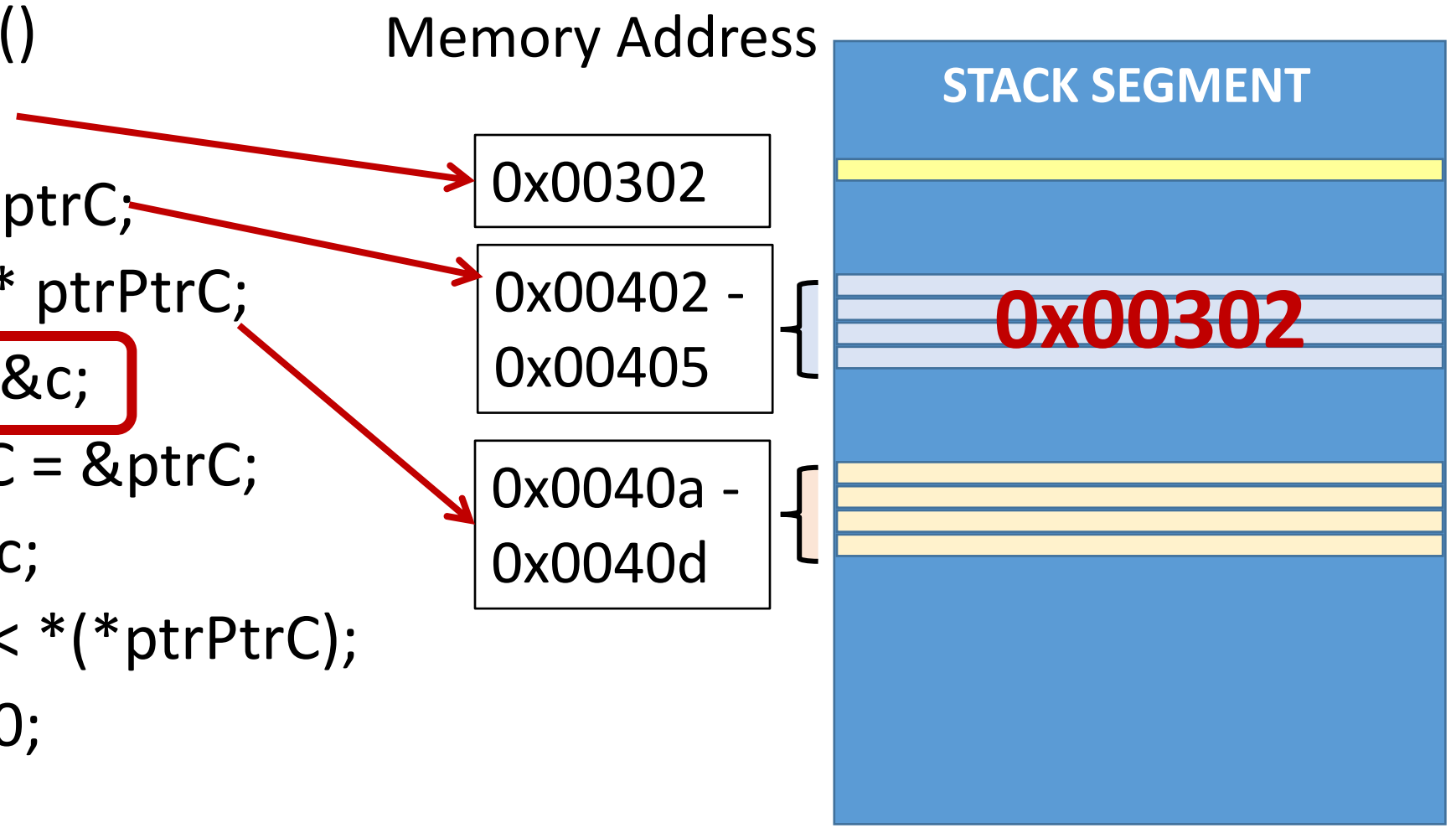

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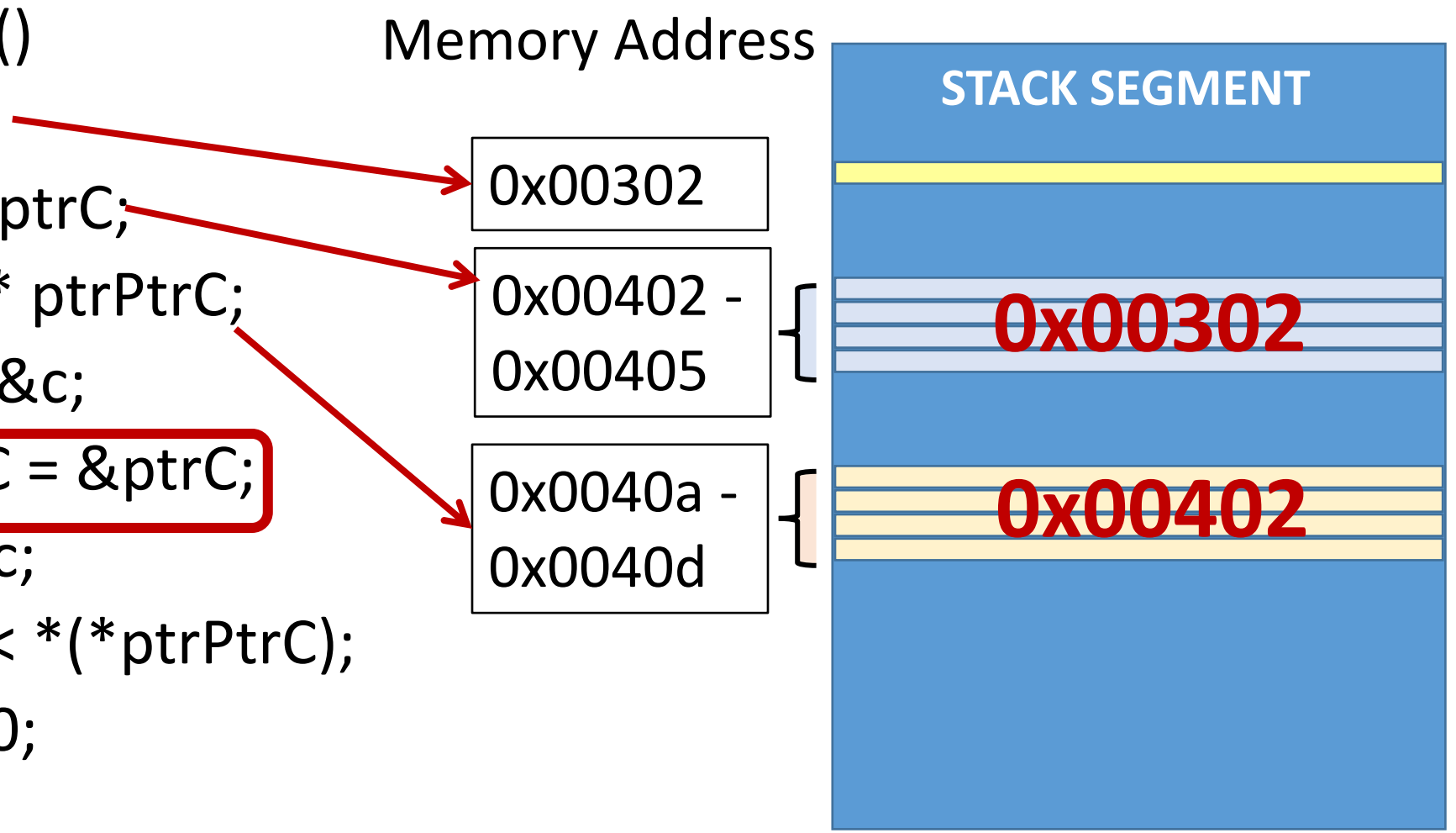

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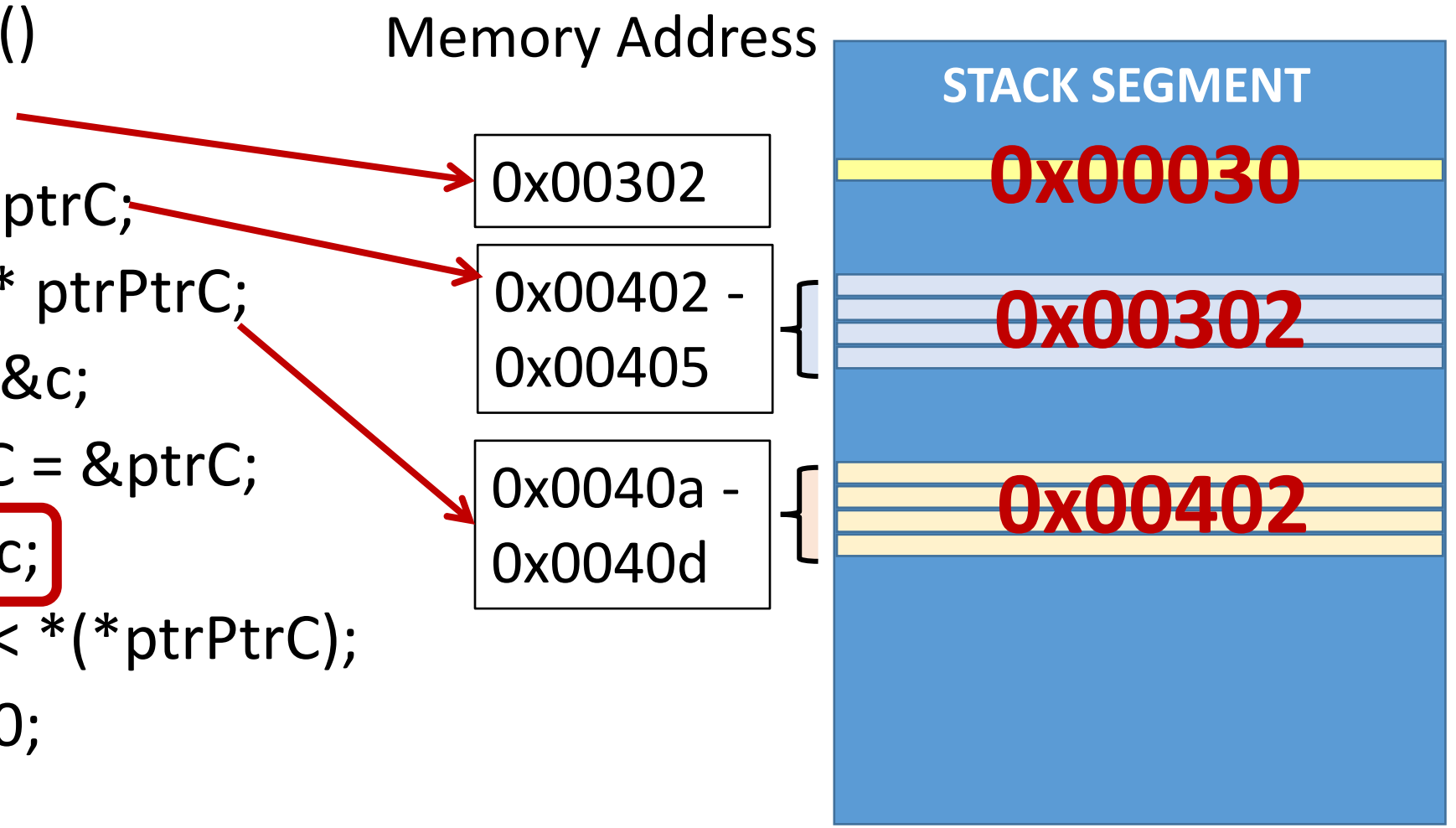

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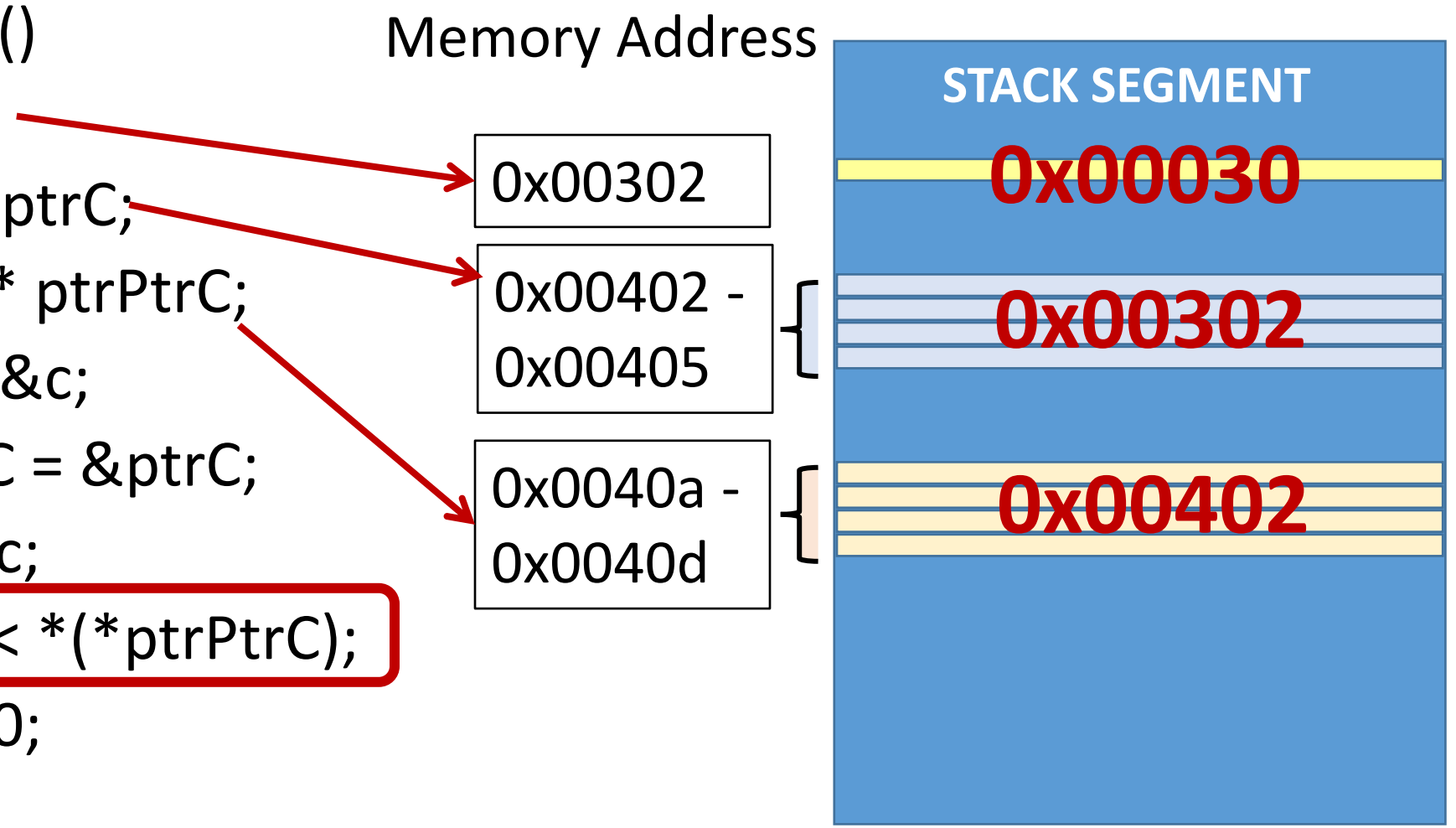
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



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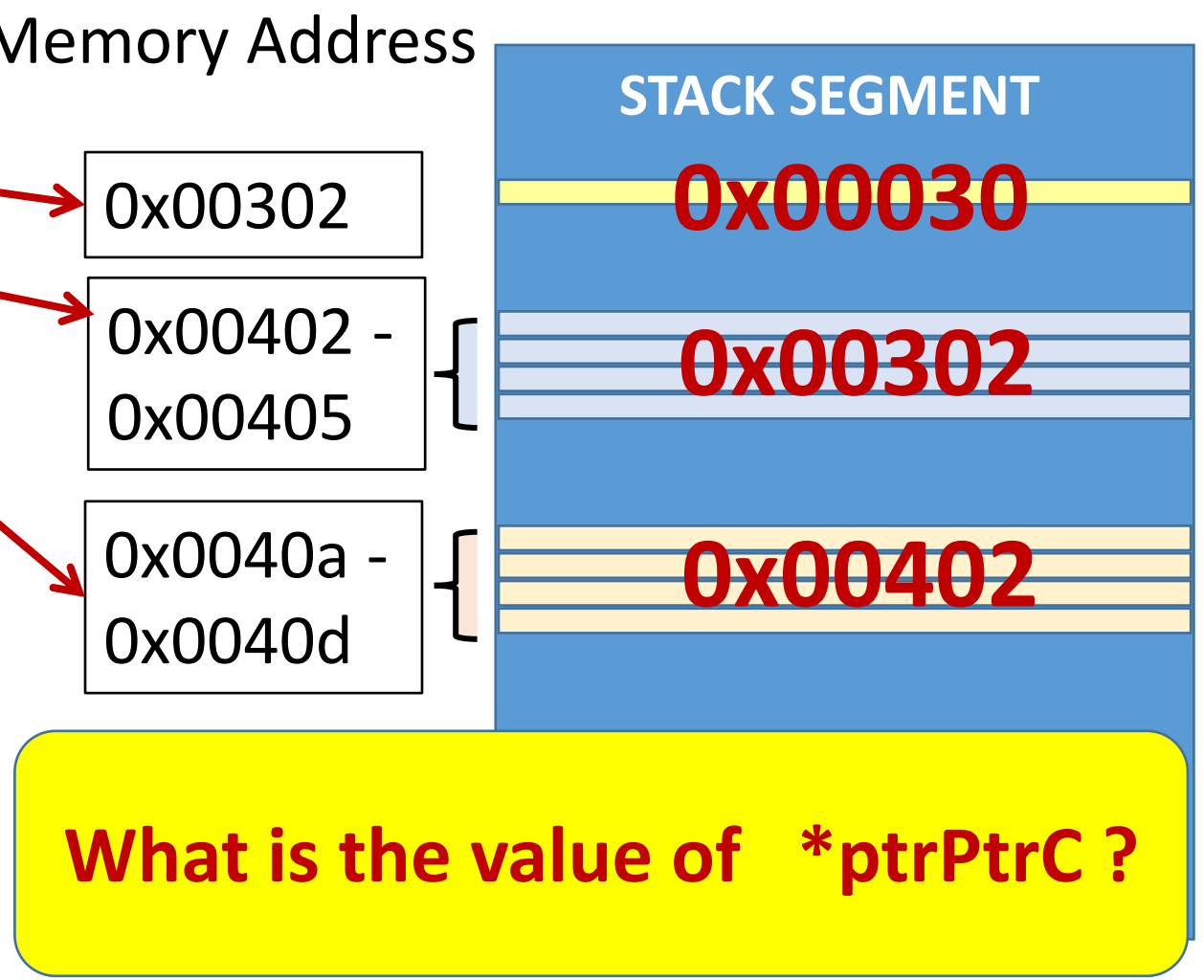

Can We Have Dereferences of Dereferences?

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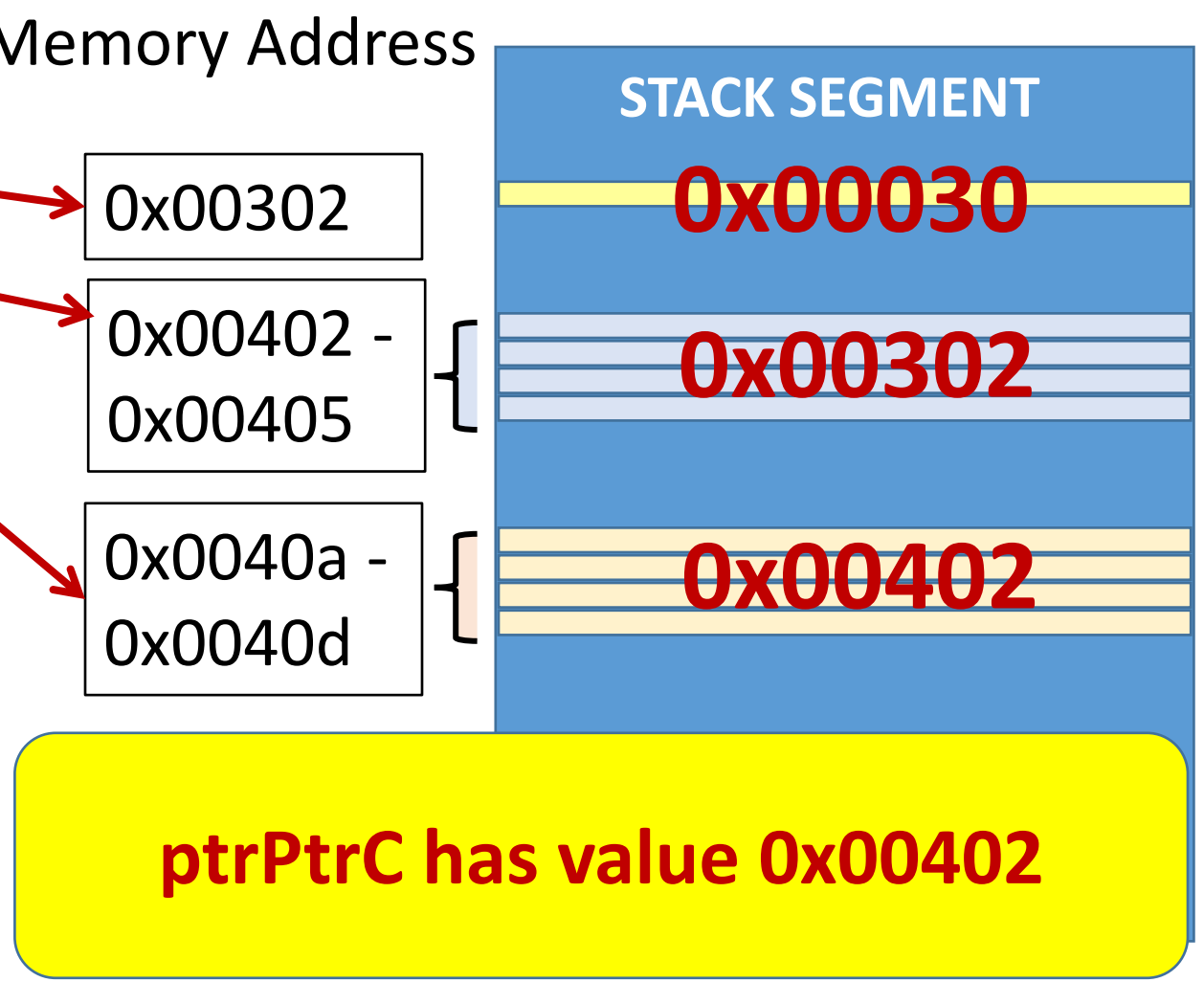
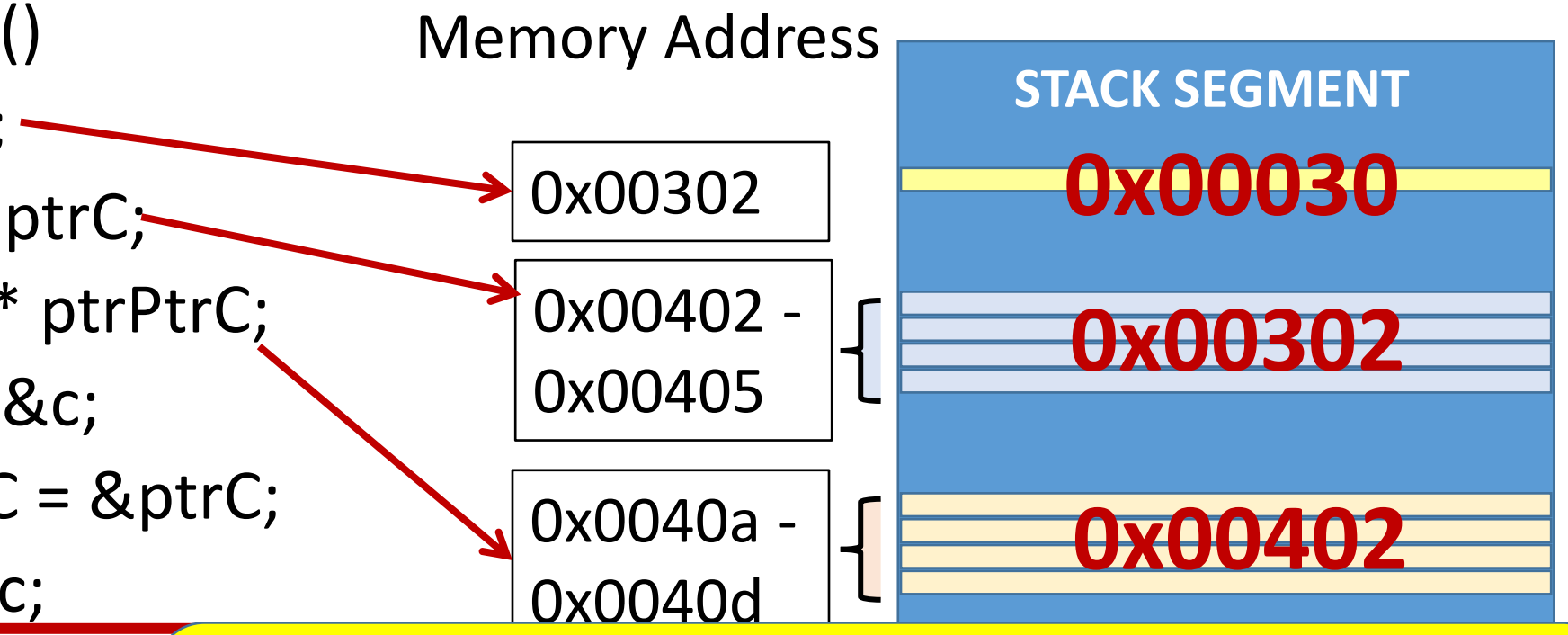


Can We Have Dereferences of Dereferences?

IIT Bombay

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



***ptrPtrC has value**
"content of memory at address 0x00402"

Can We Have Dereferences of Dereferences?

IIT Bombay

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int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
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  return 0;
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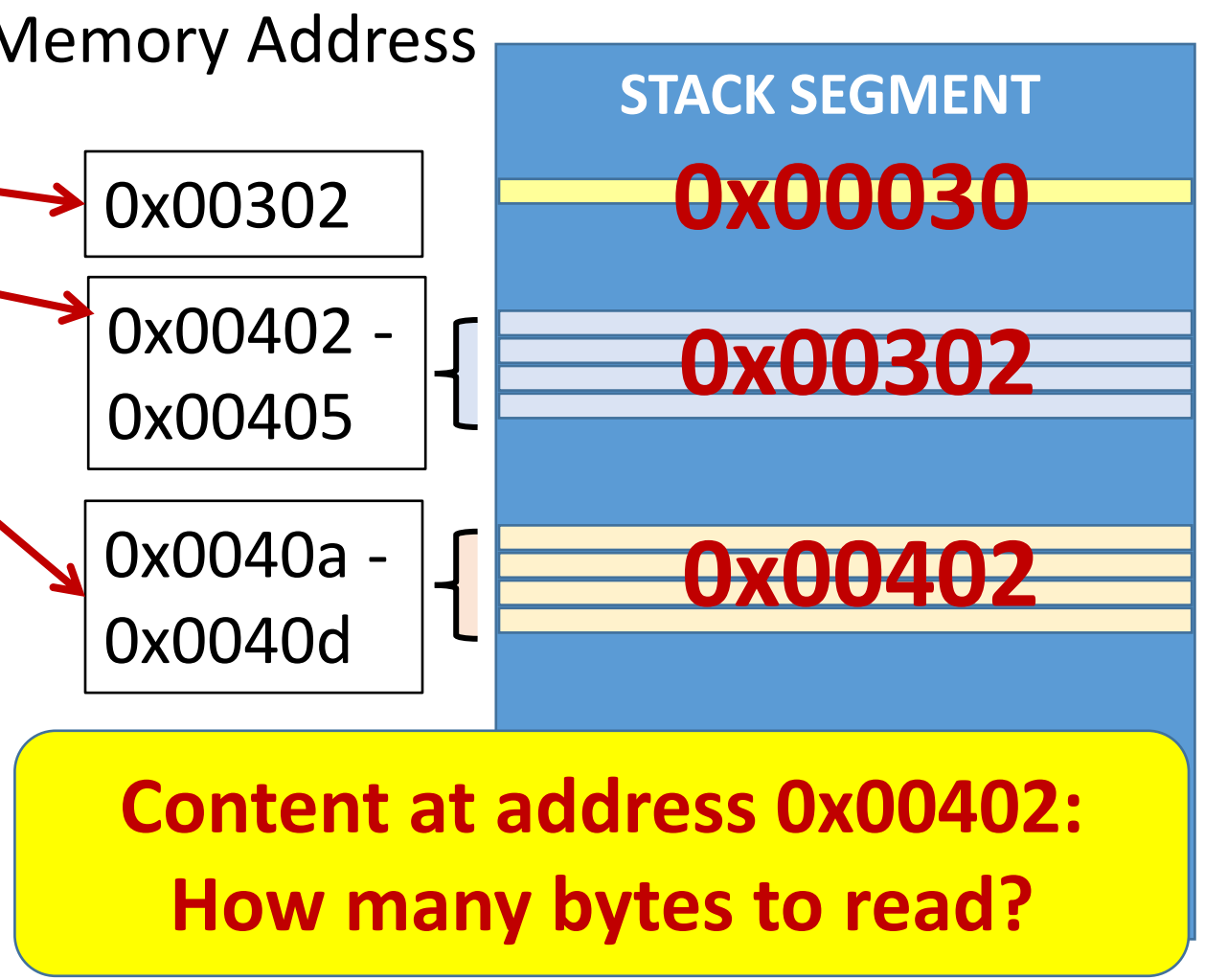

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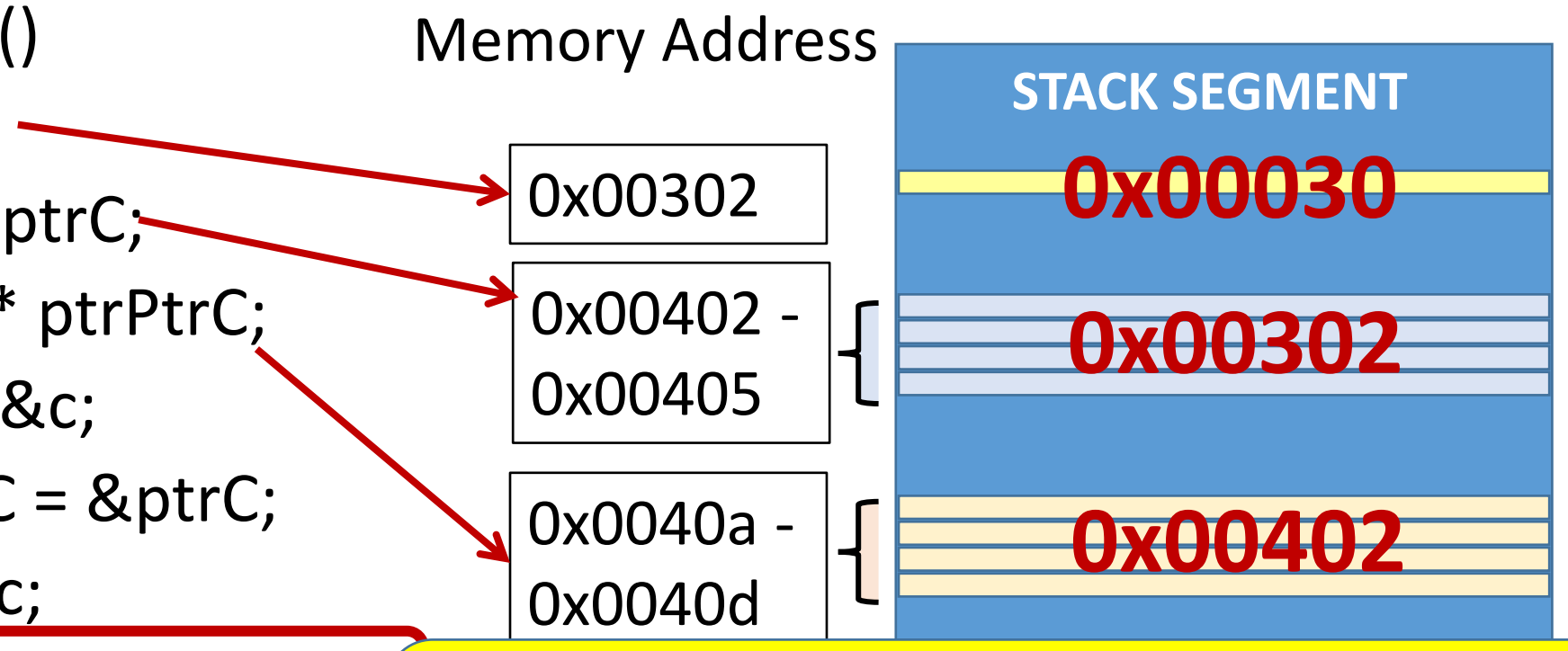
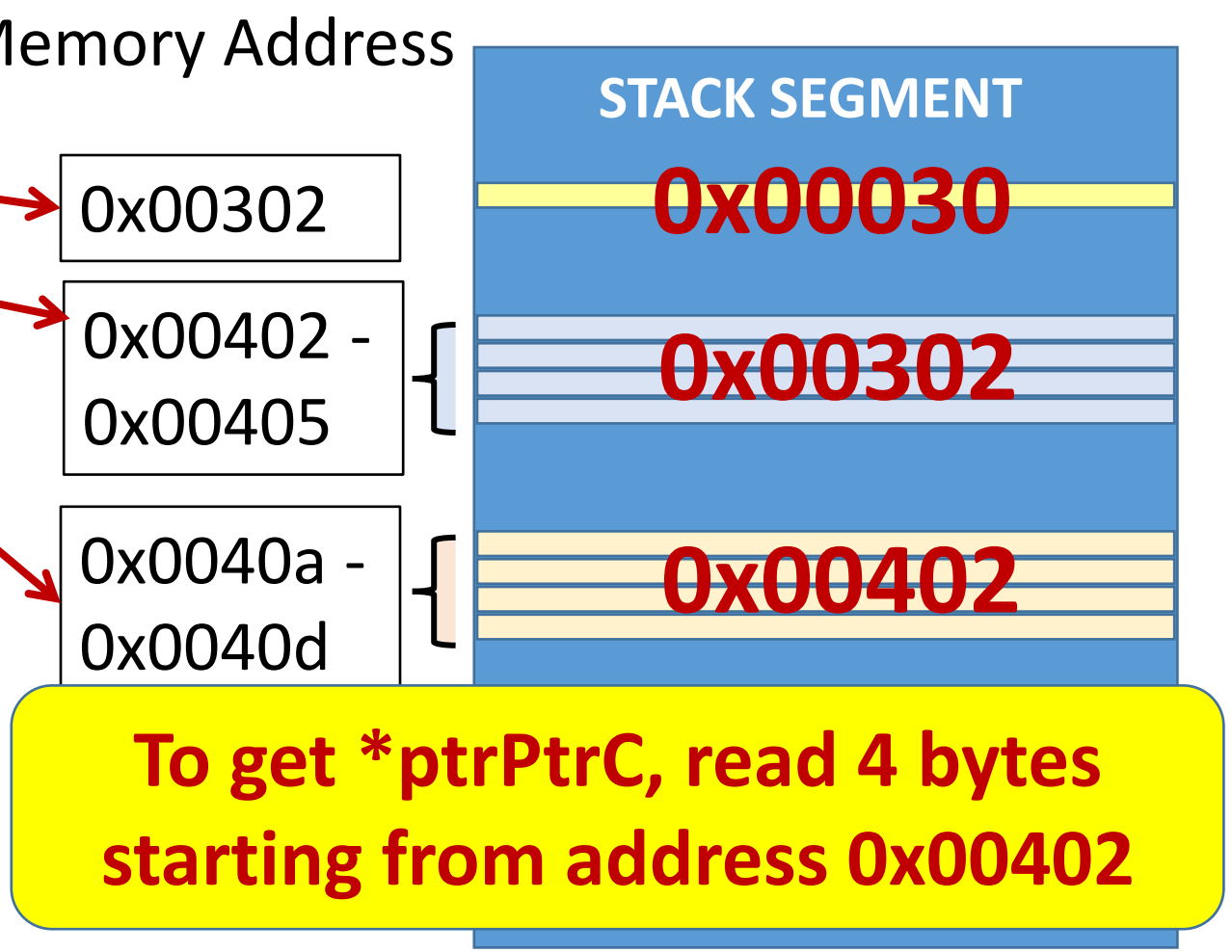


How many bytes to read?
ptrPtrC is pointer to what data type?
pointer (4 bytes)

Can We Have Dereferences of Dereferences?

IIT Bombay

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



Can We Have Dereferences of Dereferences?

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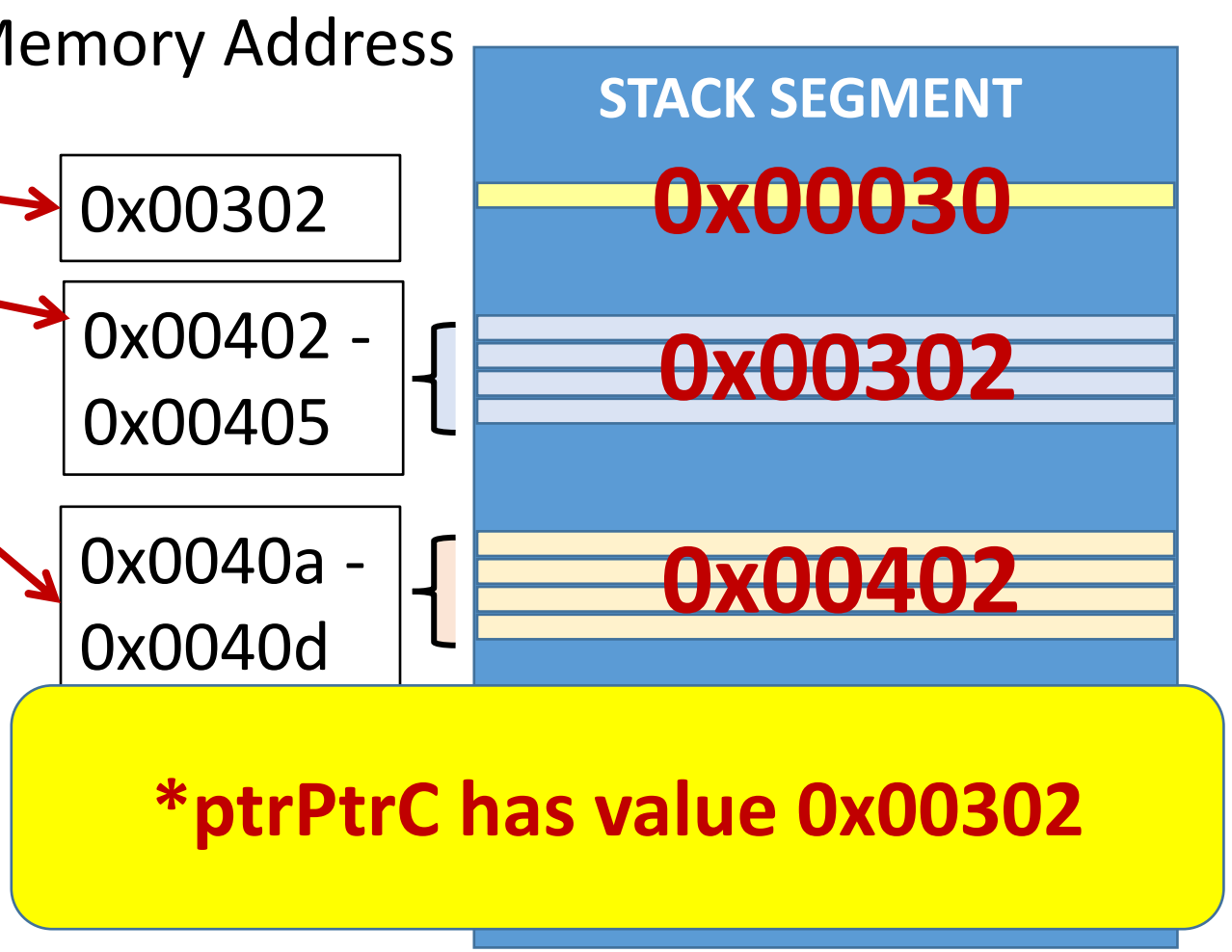
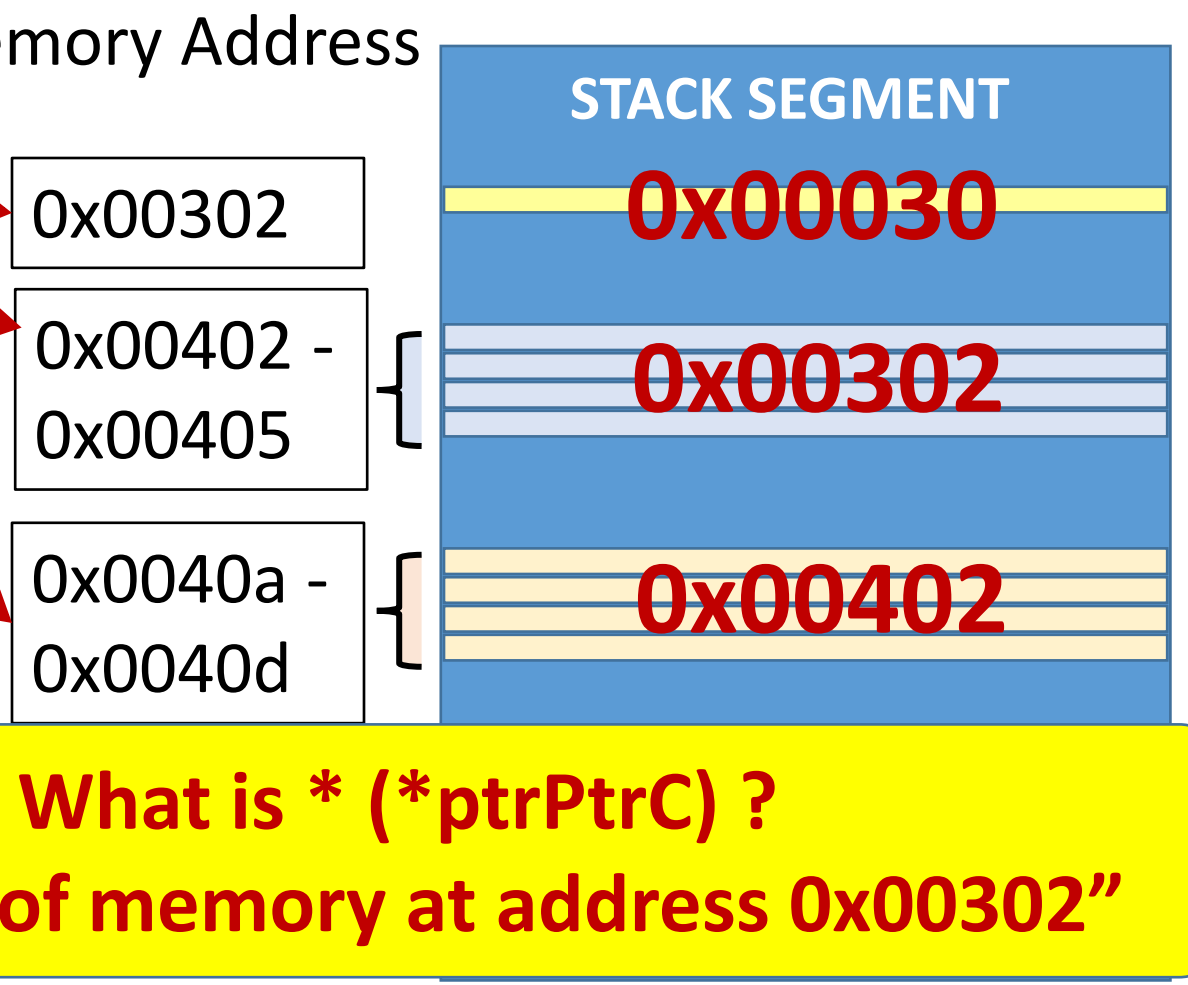
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



Can We Have Dereferences of Dereferences?

IIT Bombay

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

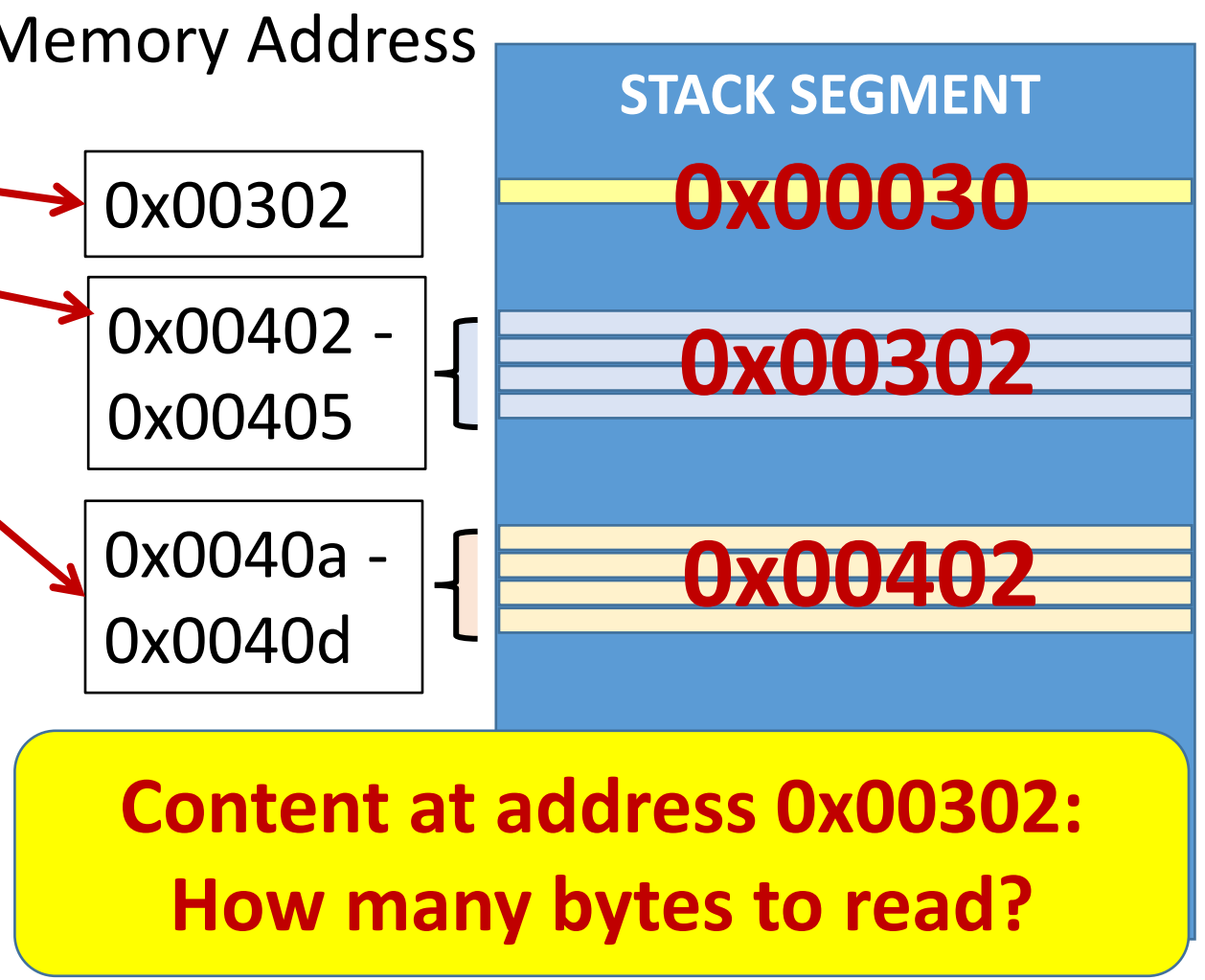


What is * (*ptrPtrC) ?
"content of memory at address 0x00302"

Can We Have Dereferences of Dereferences?

IIT Bombay

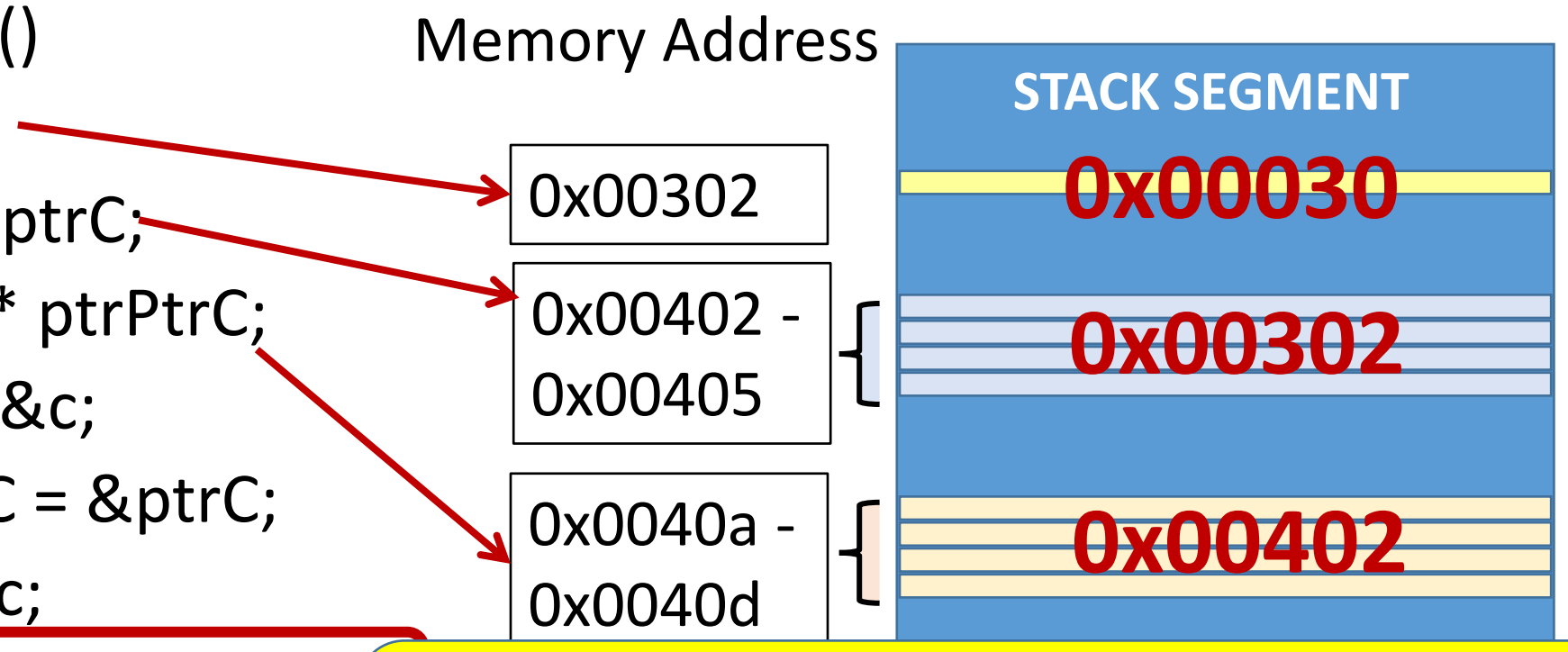
```
int main()
{  char c;
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



Can We Have Dereferences of Dereferences?

IIT Bombay

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



How many bytes to read?

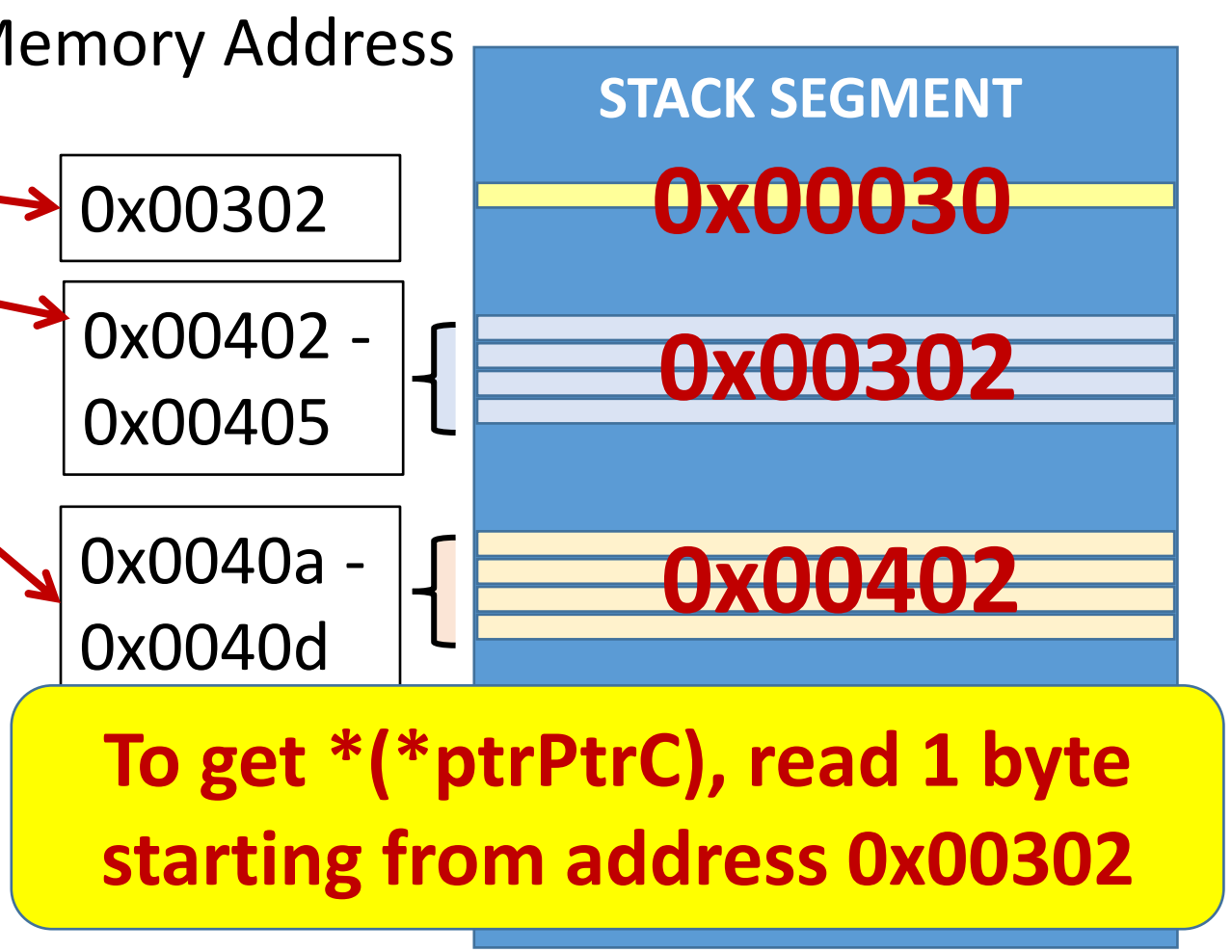
***ptrPtrC is pointer to what data type?**

char (1 byte)

Can We Have Dereferences of Dereferences?

IIT Bombay

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



Can We Have Dereferences of Dereferences?

IIT Bombay

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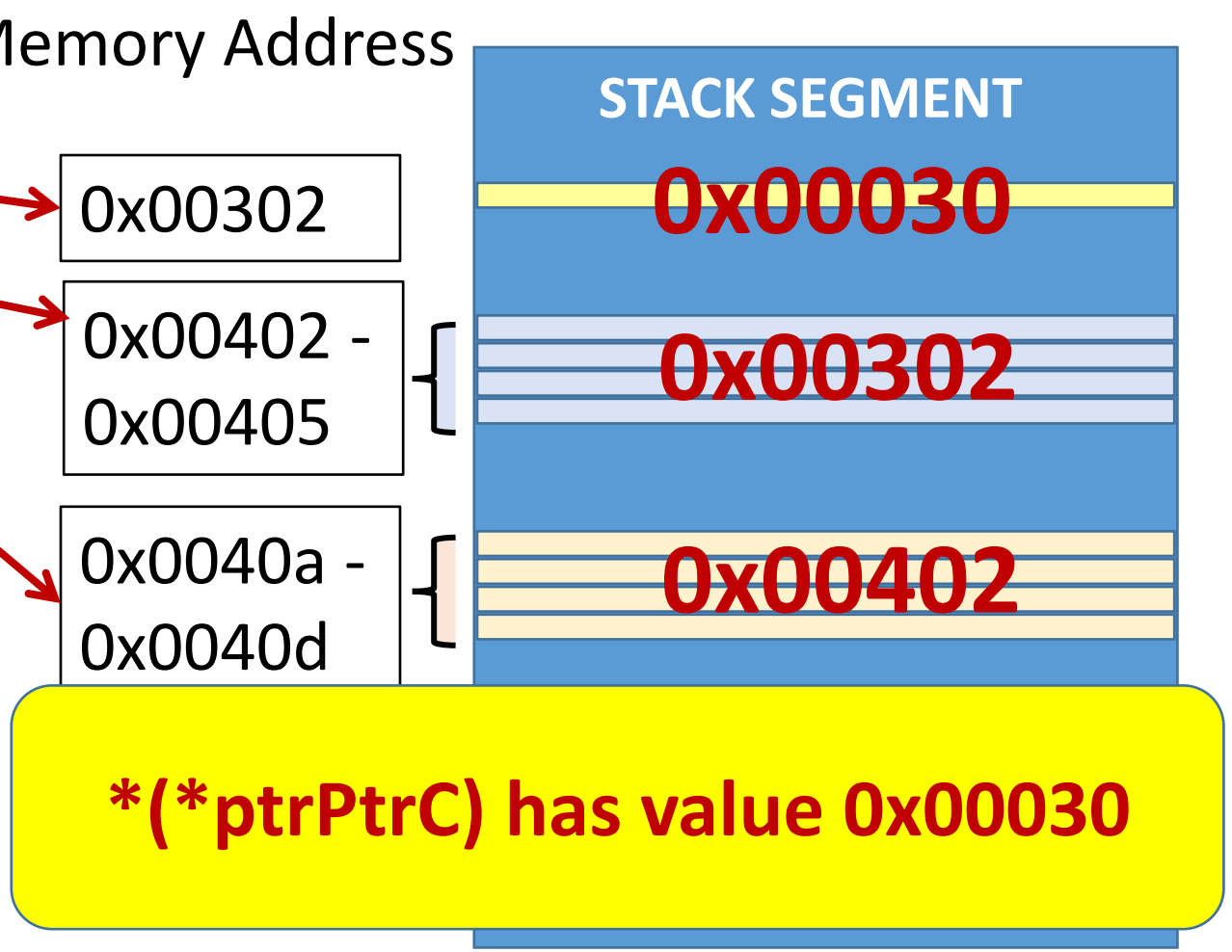
   char * ptrC;
   char ** ptrPtrC;
   ptrC = &c;
   ptrPtrC = &ptrC;
   cin >> c;
   cout << *(*ptrPtrC);
  return 0;
}
```



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

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- 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