CS 161
Intro to CS I

Recursion

Odds and Ends

- Assignment 4 due Sunday
- Questions?

<cstdlib>

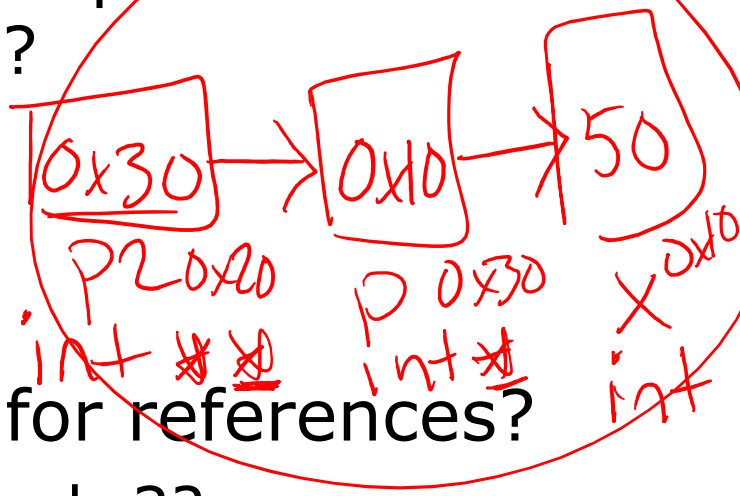
int x = atoi(s.c_str())

double y = atof(s.c_str())

C-style strings

Exercise Pointers vs. References

- What if you made a pointer (p2) that points to a pointer (p) that points to an int (x)?
  - What would the picture look like?
  - Write the code for this picture.




```
int **p2, *p, x=50;
```

- Can you make this same picture for references?
  - What if you had two references, r and r2?

```
p=&x;
p2=&p;
cout << *p; //50
cout << *p2; //0x10
cout << **p2; //50
```

Recursion = Repetition

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- What is it?
  - Function that calls itself 1 or more times (directly or indirectly)
  - Has 1 or more base case for stopping
  - Inductive reasoning: general case must eventually be reduced to a base case

Example: Drawing Rectangles

- Iterative Solution:

```
void draw_rect(int i) {
        for( ; i > 0; i--){
           cout << "******" << endl;
           cout << "*      *" << endl;
           cout << "******" << endl;
        }
  }
```

draw_rect(4);

Example: Drawing Rectangles

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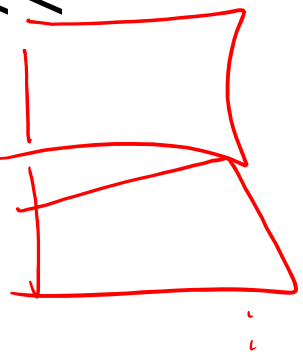
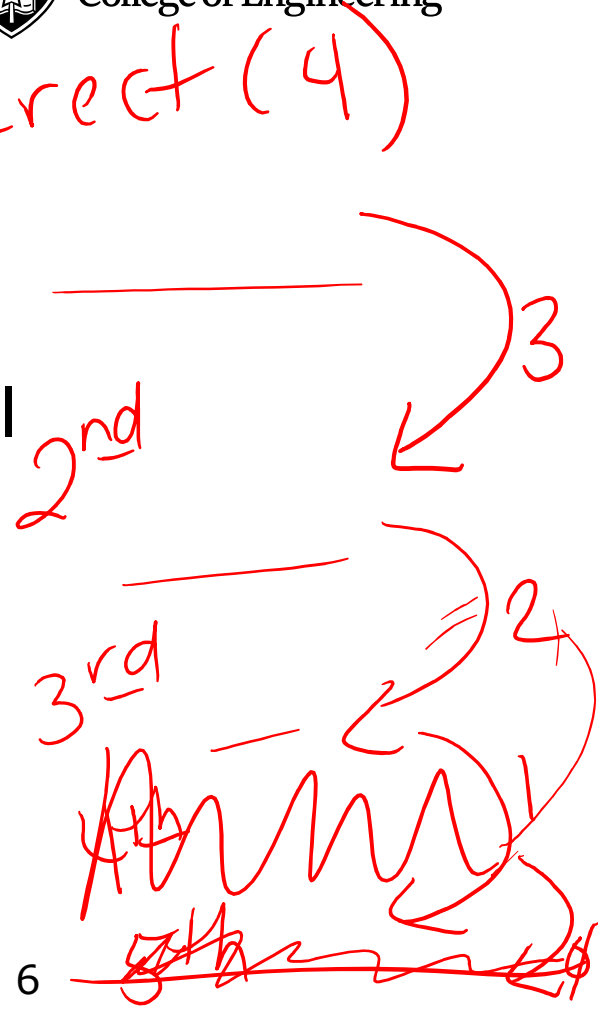
- Recursive Solution

```
void draw_rect(int i) {
        if(i>0) {       //Base case
          draw_rect(--i);    //Recursive call
          cout << "******" << endl;
          cout << "*      *" << endl;
          cout << "******" << endl;
        }
  }
```





What is different when we call after?

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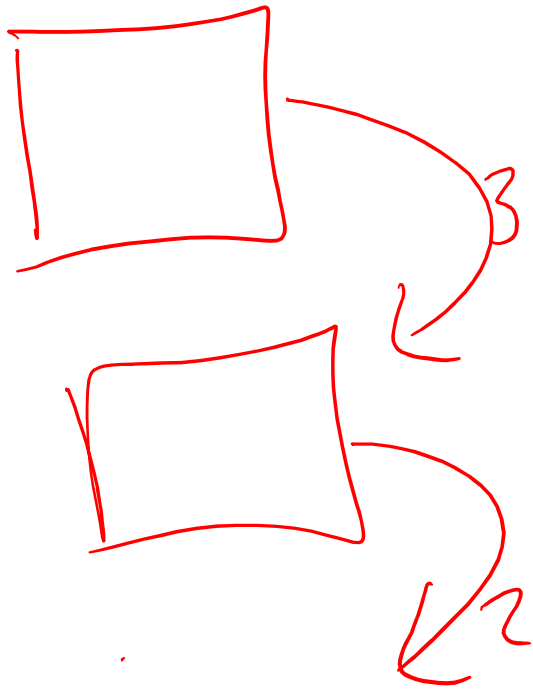
- Recursive Solution

```
void draw_rect(int i) {
        if(i>0) {       //Base case
           cout << "******" << endl;
           cout << "*      *" << endl;
           cout << "******" << endl;
           draw_rect(--i);    //Recursive call
        }
  }
```



Example: Factorial

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- Definition

  $0! = 1;$

  $n! = n * (n-1) * \ldots * (n-(n-1)) * 1 = n * (n-1)!\ ; n > 0$

Iterative Factorial

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factorial(0) = 1;
factorial(n) = n*n-1*n-2*…*n-(n-1)*1;

```
long factorial(int n) {
        long fact;
        if(n==0)
            fact=1;
        else
           for(fact=n; n > 1; n--)
              fact=fact*(n-1);
       return fact;
}
```

Recursive Factorial

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);

long factorial(int n) {
    if (n == 0)      // Base case
       return 1;
    else
       return n * factorial(n - 1);    // Recursive call
 }
```

Computing Factorial Iteratively

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factorial(0) = 1;
factorial(n) = n*(n-1)*…*2*1;

factorial(4)

Computing Factorial Iteratively

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factorial(0) = 1;
factorial(n) = n*(n-1)*...*2*1;

factorial(4) = 4 * 3

Computing Factorial Iteratively

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factorial(0) = 1;
factorial(n) = n*(n-1)*...*2*1;

factorial(4) = 4 * 3
= 12 * 2

Computing Factorial Iteratively

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```
factorial(0) = 1;
factorial(n) = n*(n-1)*...*2*1;
```

factorial(4) = 4 * 3
= 12 * 2
= 24 * 1

Computing Factorial Iteratively

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factorial(0) = 1;
factorial(n) = n*(n-1)*...*2*1;

factorial(4) = 4 * 3
= 12 * 2
= 24 * 1
= 24

Computing Factorial Recursively

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

factorial(4)

Computing Factorial Recursively

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

factorial(4) = 4 * factorial(3)

Computing Factorial Recursively

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

factorial(4) = 4 * factorial(3)
= 4 * (3 * factorial(2))

Computing Factorial Recursively

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

factorial(4) = 4 * factorial(3)
= 4 * (3 * factorial(2))
= 4 * (3 * (2 * factorial(1)))

Computing Factorial Recursively

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

factorial(4) = 4 * factorial(3)
= 4 * (3 * factorial(2))
= 4 * (3 * (2 * factorial(1)))
= 4 * (3 * (2 * (1 * factorial(0))))

Computing Factorial Recursively

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

factorial(4) = 4 * factorial(3)
= 4 * (3 * factorial(2))
= 4 * (3 * (2 * factorial(1)))
= 4 * (3 * (2 * (1 * factorial(0))))
= 4 * (3 * (2 * (1 *1)))

Computing Factorial Recursively

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

factorial(4) = 4 * factorial(3)
= 4 * (3 * factorial(2))
= 4 * (3 * (2 * factorial(1)))
= 4 * (3 * (2 * (1 * factorial(0))))
= 4 * (3 * (2 * (1 *1)))
= 4 * (3 * (2 * 1))

Computing Factorial Recursively

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

factorial(4) = 4 * factorial(3)
= 4 * (3 * factorial(2))
= 4 * (3 * (2 * factorial(1)))
= 4 * (3 * (2 * (1 * factorial(0))))
= 4 * (3 * (2 * (1 *1)))
= 4 * (3 * (2 * 1))
= 4 * (3 * 2)

Computing Factorial Recursively

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

factorial(4) = 4 * factorial(3)
= 4 * (3 * factorial(2))
= 4 * (3 * (2 * factorial(1)))
= 4 * (3 * (2 * (1 * factorial(0))))
= 4 * (3 * (2 * (1 *1)))
= 4 * (3 * (2 * 1))
= 4 * (3 * 2)
= 4 * 6

Computing Factorial Recursively

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```
factorial(0) = 1;
factorial(n) = n*factorial(n-1);
```

```
factorial(4) = 4 * factorial(3)
             = 4 * (3 * factorial(2))
             = 4 * ( 3 * (2 * factorial(1)))
             = 4 * ( 3 * ( 2 * (1 * factorial(0))))
             = 4 * ( 3 * ( 2 * (1 *1)))
             = 4 * ( 3 * ( 2 * 1))
             = 4 * (3 * 2)
             = 4 * 6
             = 24
```

Differences

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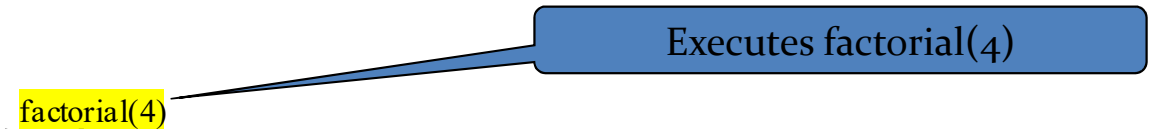
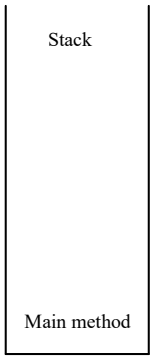
- Pros
  - Readability
- Cons
  - Efficiency
  - Memory

Recursive Factorial





Recursive Factorial

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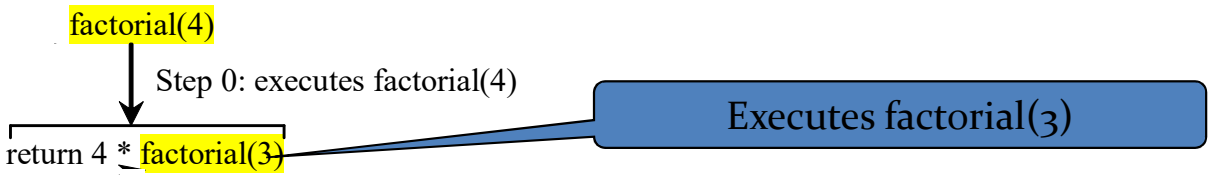
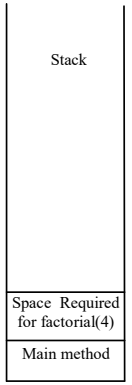
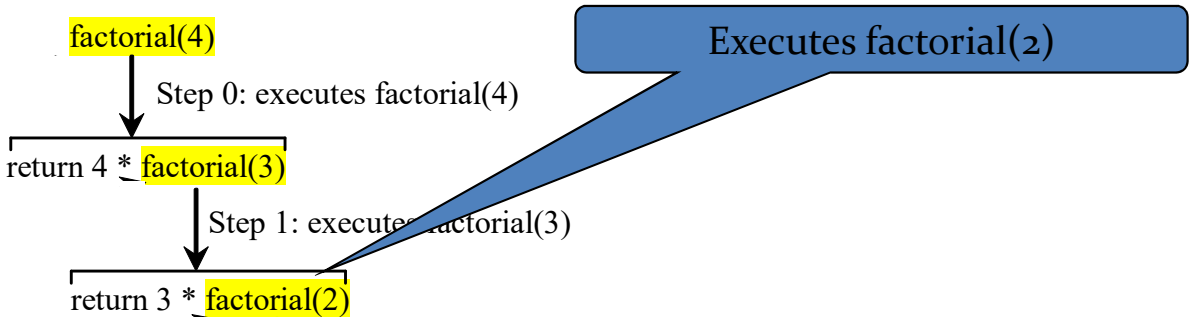
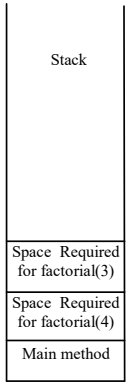




Recursive Factorial





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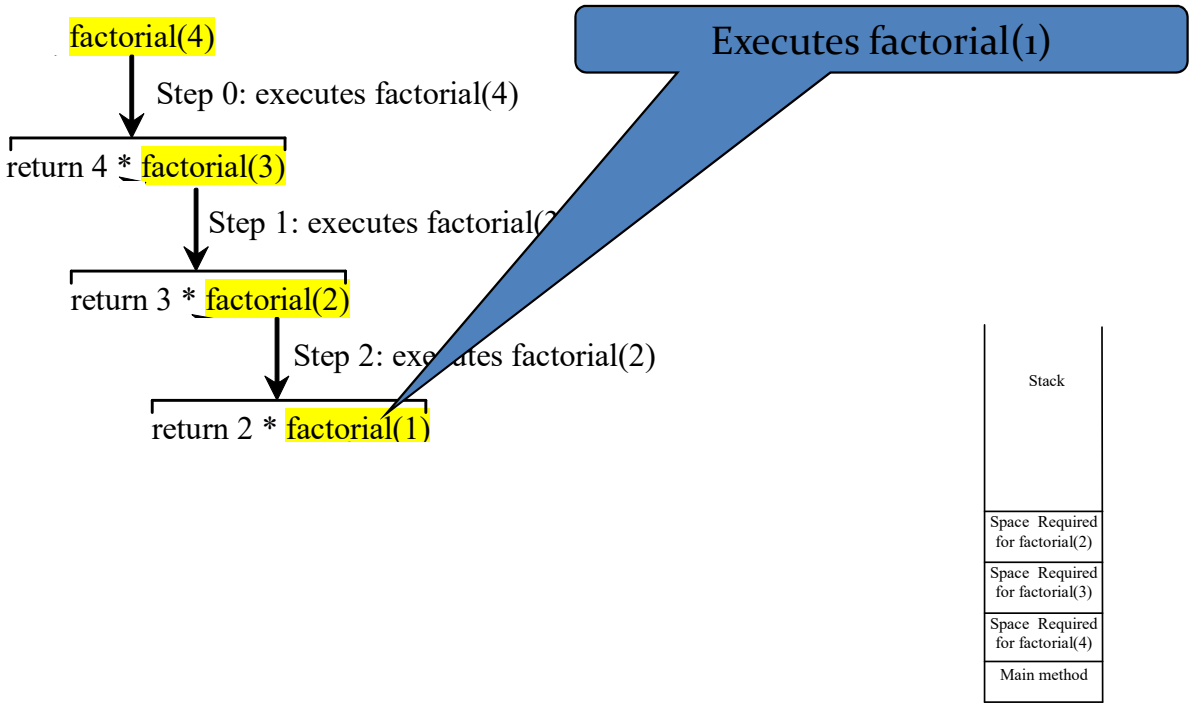

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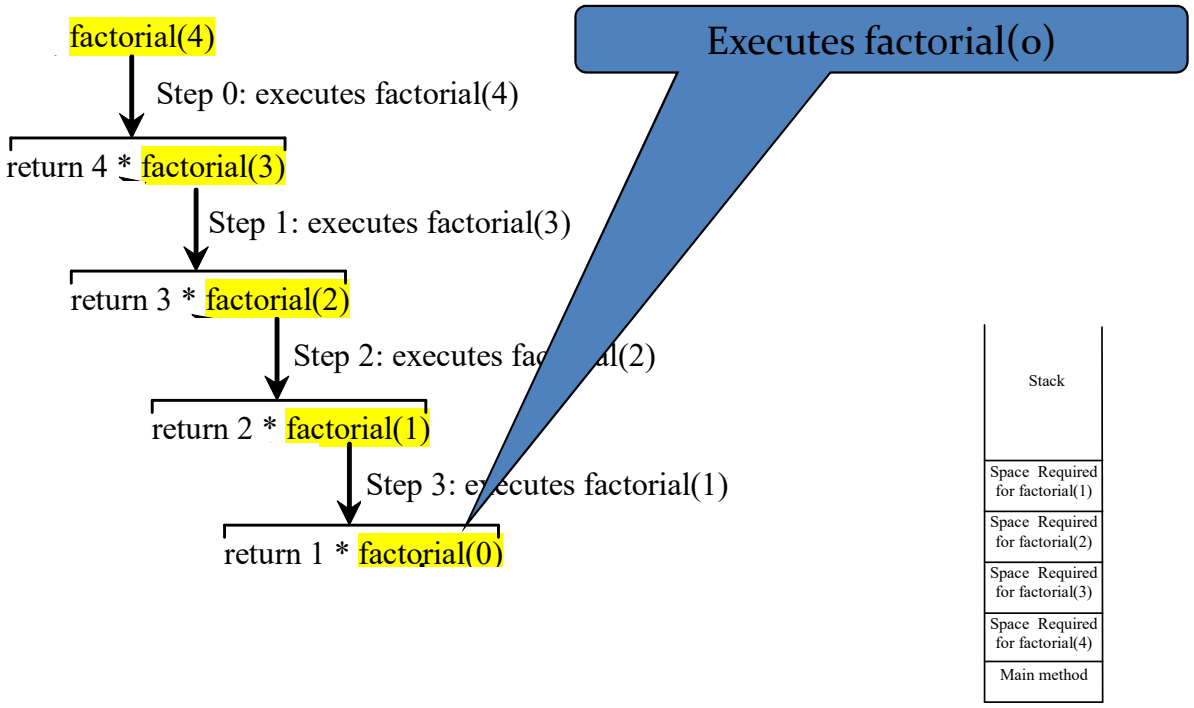

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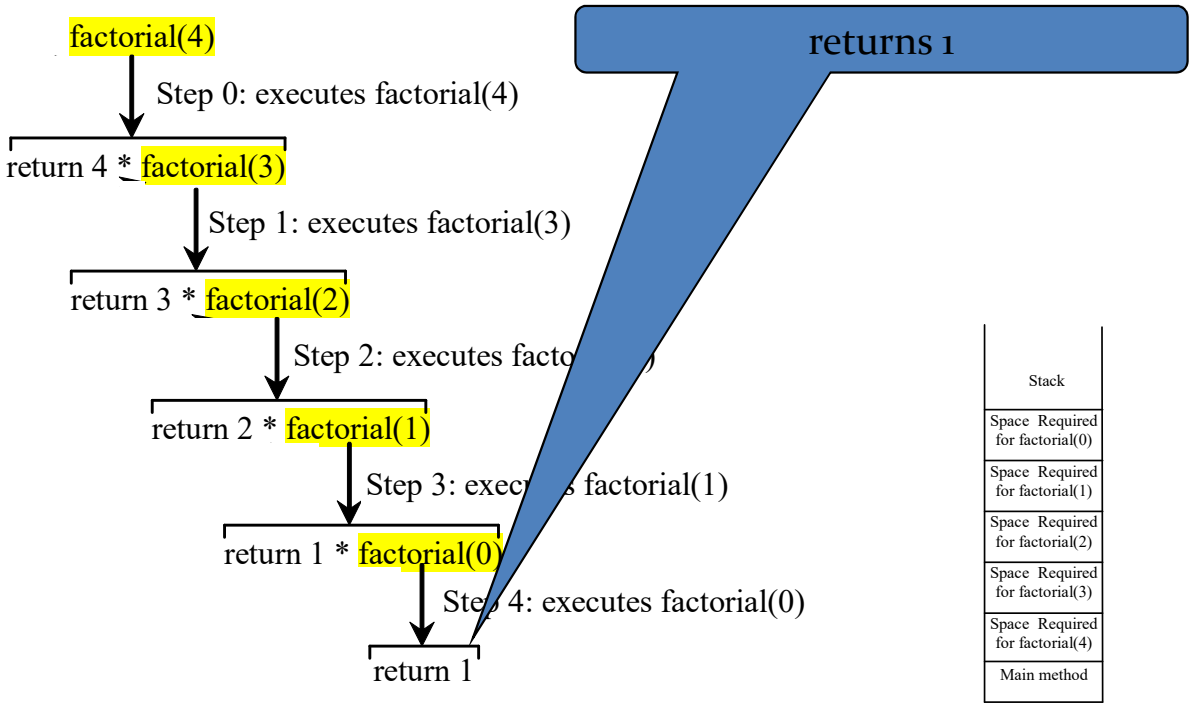

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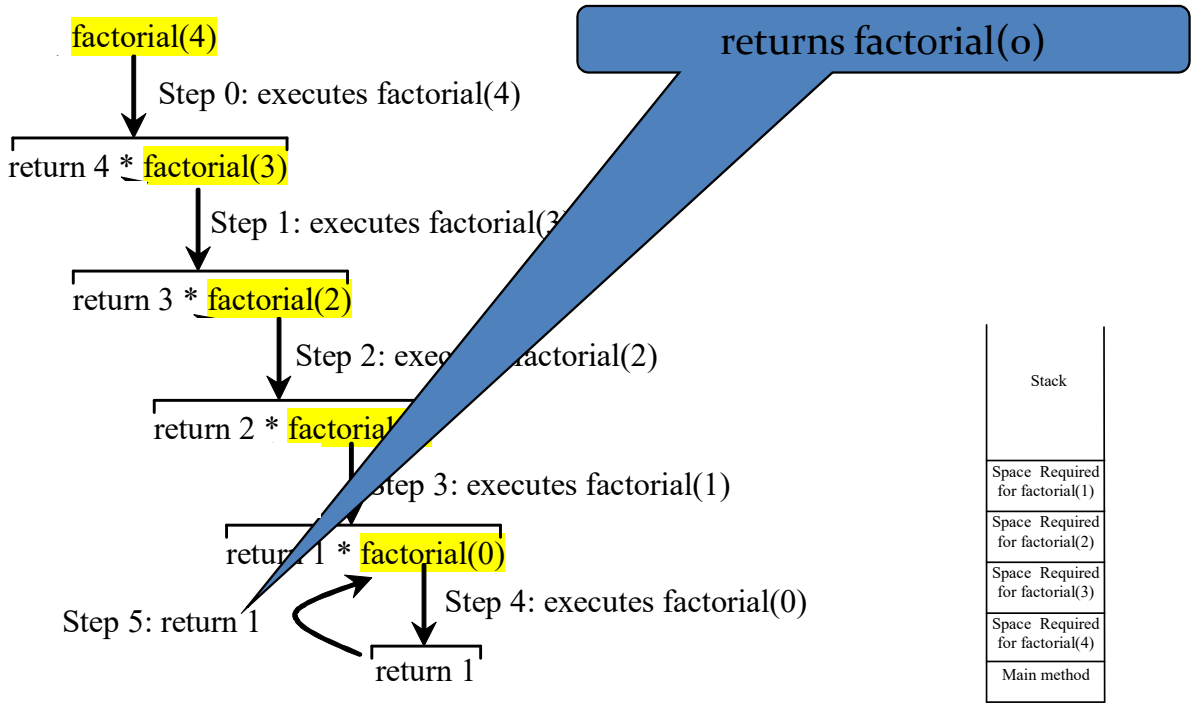

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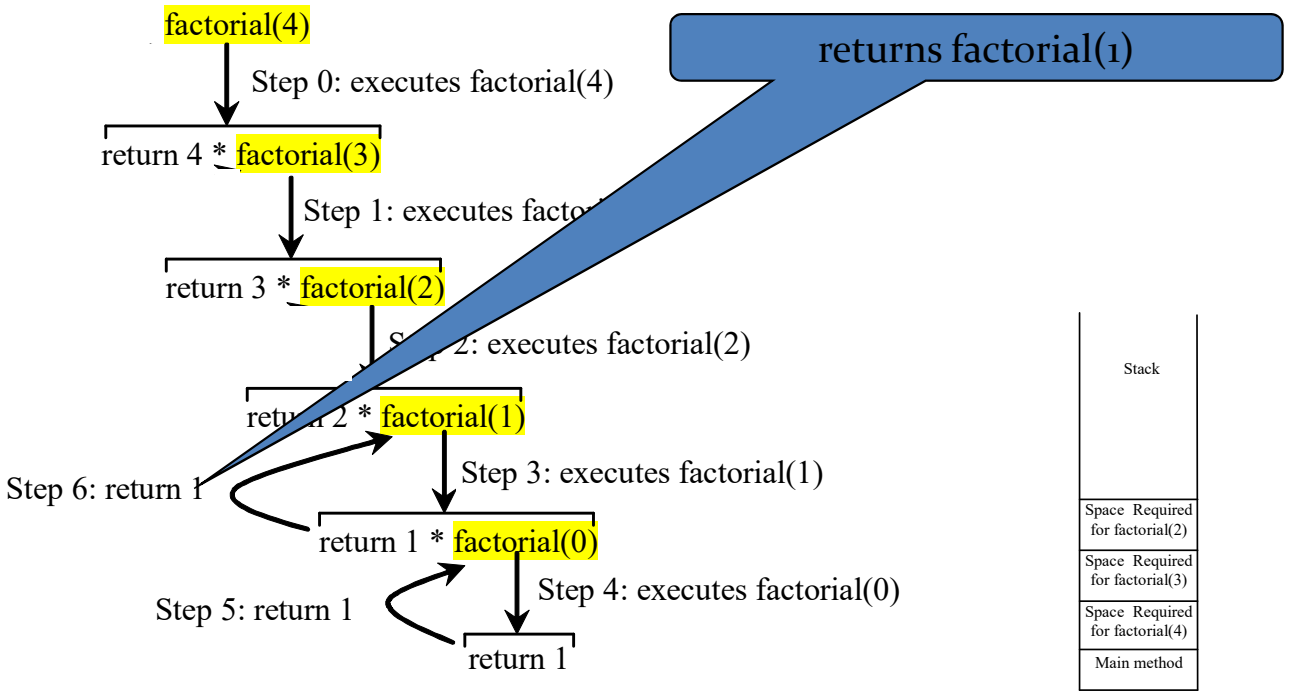

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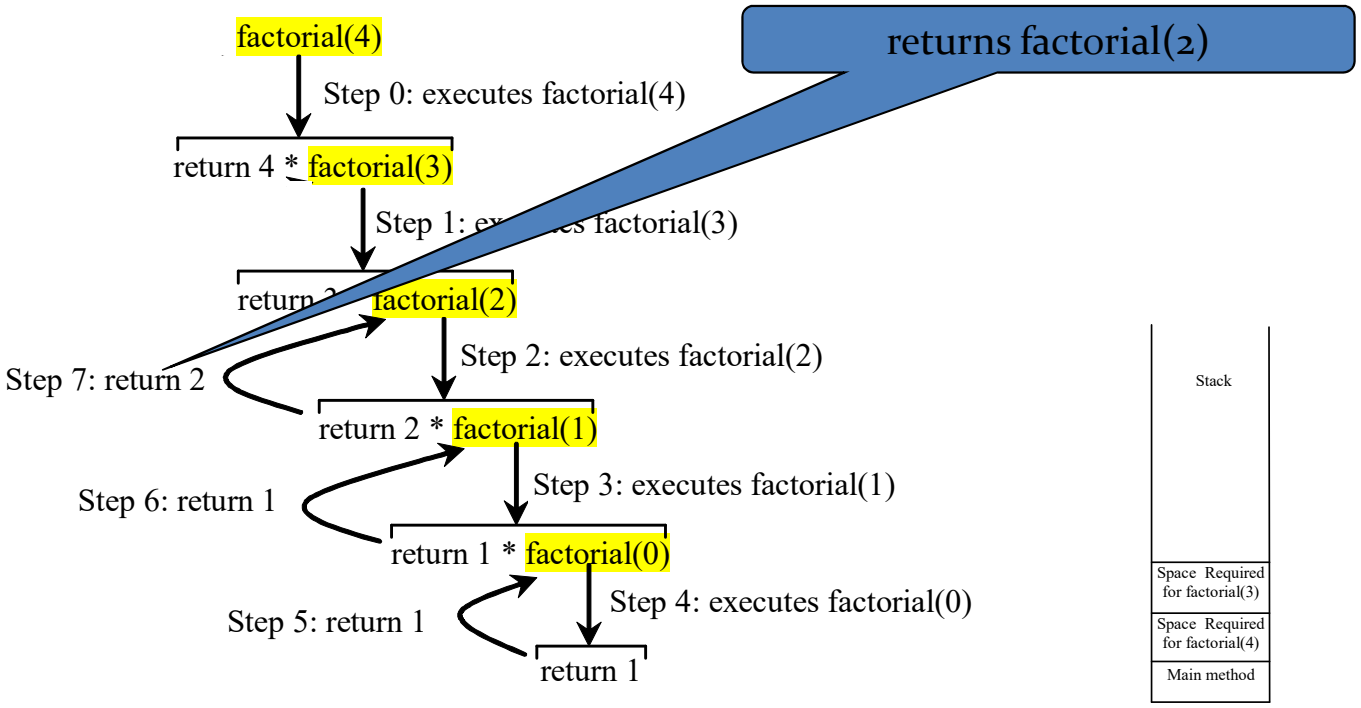

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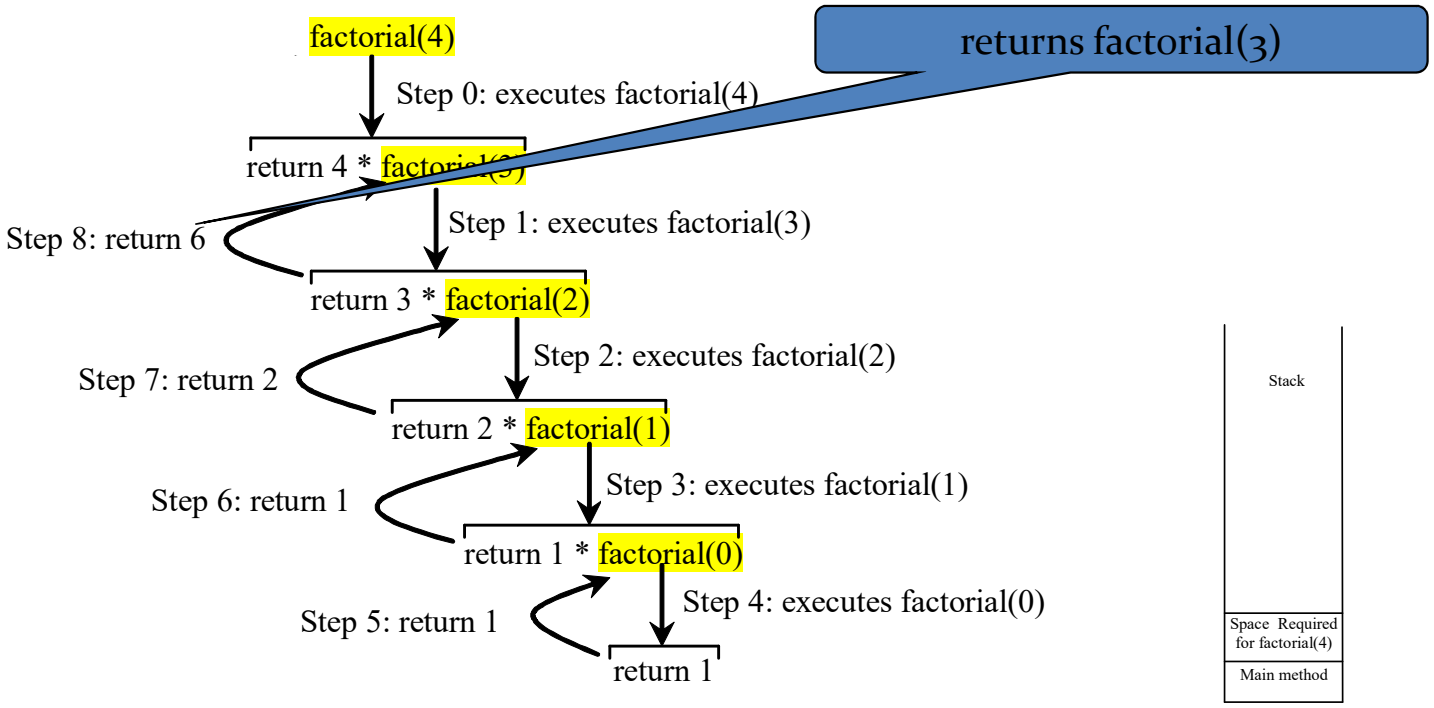

Recursive Factorial

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