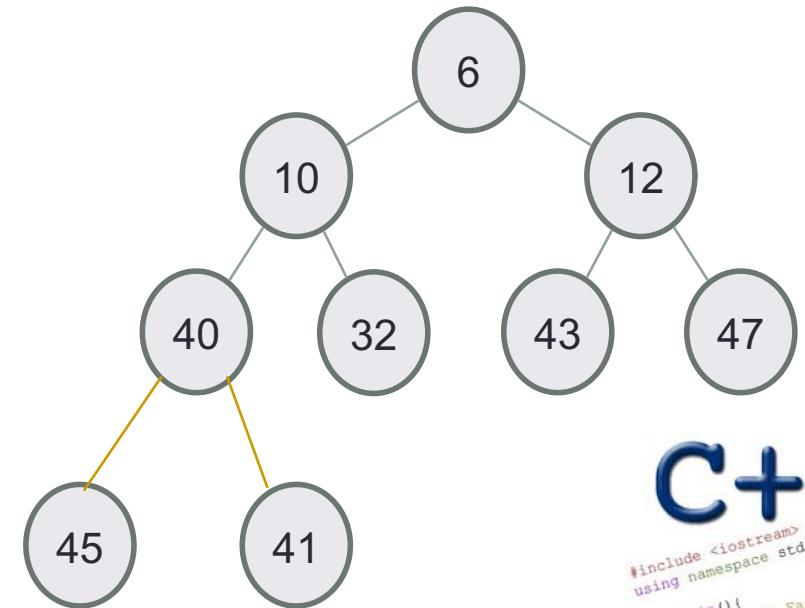
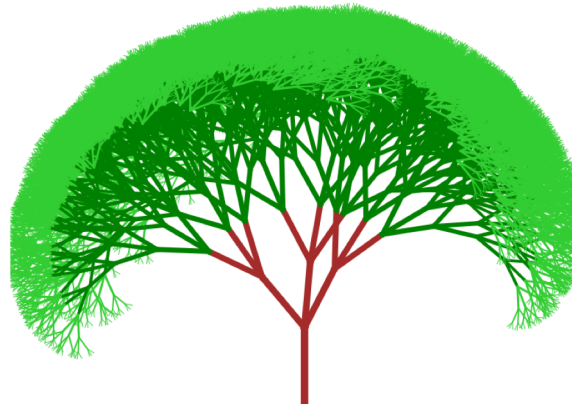


MORE ON RECURSION



Problem Solving with Computers-I



C++

```
#include <iostream>
using namespace std;

int main(){
    cout<<"Hola Facebook!";
    return 0;
}
```

Last class: *this is legal!*

```
int fac(int N) {  
    return N * fac(N-1) ;  
}
```

legal != recommended

```
int fac(int N) {  
    return N * fac(N-1) ;  
}
```

No *base case* -- the calls to **fac** will never stop (nicely)!

Make sure you have a
base case, *then* worry
about the recursion...



```
int fac(int N) {  
    return fac(N) ;  
}
```

Roadsigns and recursion

examples of self-fulfilling danger

Thinking recursively !

```
int fac(int N) {
```

```
    if (N <= 1)  
        return 1;
```

} Base case

```
}
```

Thinking recursively !

```
int fac(int N) {  
    if (N <= 1) } Base case  
        return 1;  
  
    else{  
        int rest = fac(N-1) ; } Recursive  
        return rest * N; } case  
    }
```

Human: Base case and 1 step

Computer: Everything else


Thinking recursively !

```
int fac(int N) {  
    if (N <= 1)           } Base case  
        return 1;  
  
    else  
        return fac(N-1) * N; } Recursive case  
                                (shorter version)  
}
```

Human: Base case and 1 step

Computer: Everything else

Behind the curtain...

```
int fac(int N){  
    if (N <= 1)  
         return 1  
    else  
        return N * fac(N-1);  
}
```

```
cout<<fac(1);
```

Result: 1

The base case is **No Problem!**

Behind the curtain...

```
int fac(int N){  
    if (N <= 1)  
        return 1  
  
    else  
        return N * fac(N-1) ;  
}
```

fac(5)

Behind the curtain...

```
int fac(int N){  
    if (N <= 1)  
        return 1  
  
    else  
        return N * fac(N-1);  
}
```

fac(5)



5 * fac(4)

Behind the curtain...

```
int fac(int N){  
    if (N <= 1)  
        return 1  
  
    else  
        return N * fac(N-1);  
}
```

fac(5)

┌───────────┐

5 * fac(4)

┌───────────┐

4 * fac(3)

Behind the curtain...

```
int fac(int N){  
    if (N <= 1)  
        return 1  
  
    else  
        return N * fac(N-1);  
}
```

fac(5)



5 * fac(4)



4 * fac(3)



3 * fac(2)

```
int fac(int N){
```

```
    if (N <= 1)  
        return 1
```

```
    else  
        return N * fac(N-1);
```

```
}
```

Behind the curtain...

fac(5)

┌───────────┐

5 * fac(4)

┌───────────┐

4 * fac(3)

┌───────────┐

3 * fac(2)

┌───────────┐

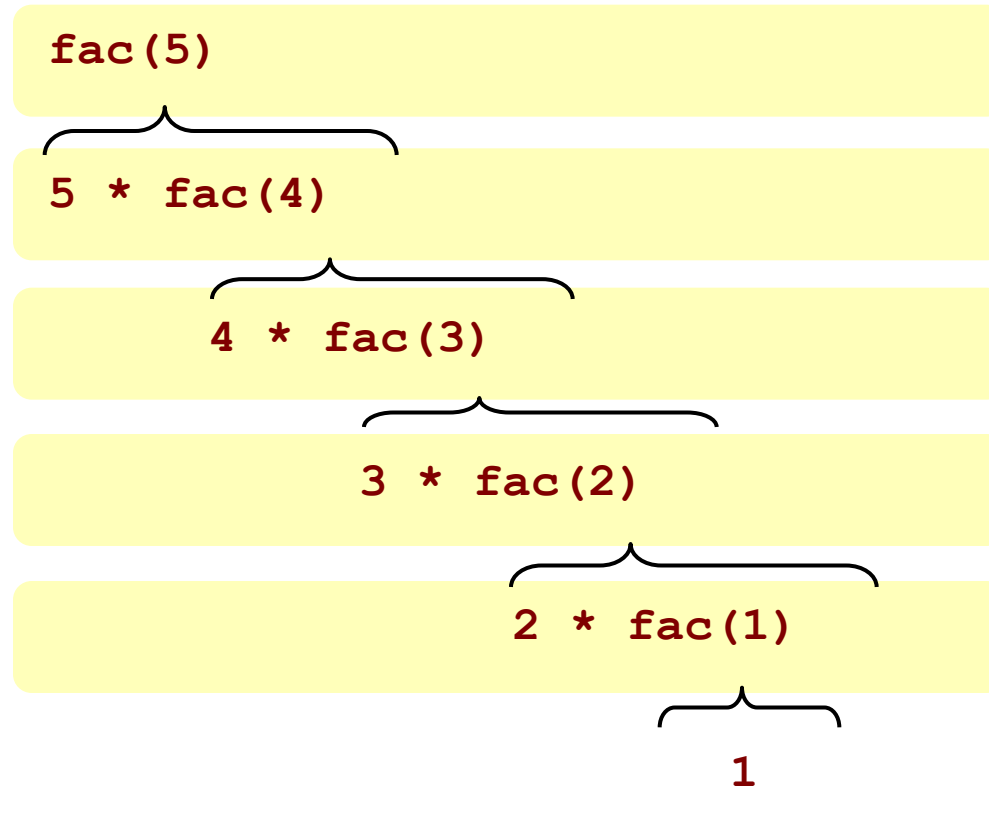
2 * fac(1)

```
int fac(int N){  
    if (N <= 1)  
        return 1  
  
    else  
        return N * fac(N-1);  
}
```

Behind the curtain...

"The Stack"

Remembers
all of the
individual
calls to **fac**



```
int fac(int N){
```

```
    if (N <= 1)  
        return 1
```

```
    else  
        return N * fac(N-1);
```

```
}
```

Behind the curtain...

fac(5)

┌───────────┐

5 * fac(4)

┌───────────┐

4 * fac(3)

┌───────────┐

3 * fac(2)

┌───────────┐

2 * 1

```
int fac(int N){
```

```
    if (N <= 1)  
        return 1
```

```
    else  
        return N * fac(N-1);
```

```
}
```

Behind the curtain...

fac(5)

┌───────────┐

5 * fac(4)

┌───────────┐

4 * fac(3)

┌───────────┐

3 * 2

Behind the curtain...

```
int fac(int N){  
    if (N <= 1)  
        return 1  
  
    else  
        return N * fac(N-1);  
}
```

fac(5)

┌───────────┐

5 * fac(4)


┌───────────┐

4 * 6

Behind the curtain...

```
int fac(int N){  
    if (N <= 1)  
        return 1  
  
    else  
        return N * fac(N-1);  
}
```

fac(5)



5 * 24

Behind the curtain...

```
int fac(int N){  
    if (N <= 1)  
        return 1  
  
    else  
        return N * fac(N-1);  
}
```

fac(5)

Result: 120

Let recursion do the work for you.

Exploit self-similarity	}	Less work !
Produce short, elegant code		

Let recursion do the work for you.

Exploit self-similarity
Produce short, elegant code

} **Less work !**

```
int fac(int N) {  
    if (N <= 1)  
        return 1;  
    else{  
        int rest = fac(N-1);  
        return rest * N;  
    }  
}
```


You handle the base case –
the easiest case!

Recursion does almost all of
the rest of the problem!

You specify one
step at the end

But you ***do*** need to do one step yourself...

```
int fac(int N) {  
    if (N <= 1)  
        return 1;  
    else:  
        return fac(N) ;  
}
```



This will not work !

Searching a linked list

Given a linked list, implement a recursive search function

- Return True if a given value is present in the list
- Otherwise return False

Recursive function to free nodes in a linked list

Given a linked list, implement a recursive function to delete all the nodes in the linked list

Binary Search: Efficient search in a sorted array

- **Binary search.** Given `value` and sorted array `a[]`, find index `i` such that `a[i] = value`, or report that no such index exists.
- **Invariant.** Algorithm maintains $a[lo] \leq value \leq a[hi]$.
- Ex. Binary search for 33.

[illegible]

Binary Search

- Ex. Binary search for 33.

6	13	14	25	33	43	51	53	64	72	84	93	95	96	97
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
↑							↑							↑
lo							mid							hi

Binary Search

- Ex. Binary search for 33.

6	13	14	25	33	43	51	53	64	72	84	93	95	96	97
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
↑						↑								
lo						hi								

Binary Search

- Ex. Binary search for 33.

6	13	14	25	33	43	51	53	64	72	84	93	95	96	97
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
↑ lo			↑ mid			↑ hi								

Binary Search

- Ex. Binary search for 33.

6	13	14	25	33	43	51	53	64	72	84	93	95	96	97
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
				↑		↑								
				lo		hi								

Binary Search

- Ex. Binary search for 33.

6	13	14	25	33	43	51	53	64	72	84	93	95	96	97
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
				↑	↑	↑								
				lo	mid	hi								

