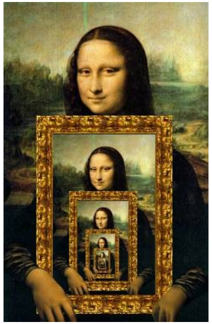
Freq.
AC

Recursion

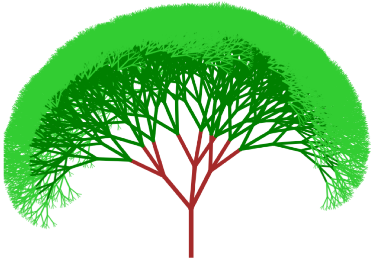
a.k.a., CS's version of mathematical induction

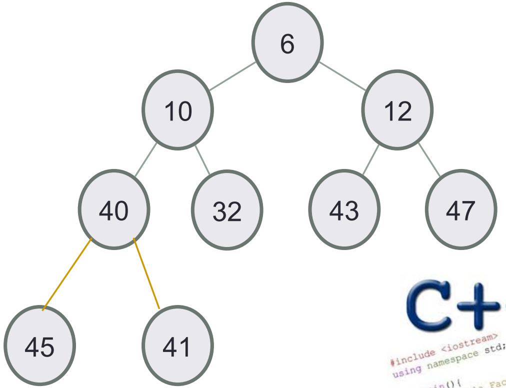
As close as CS gets to magic



GNU
is not Unix

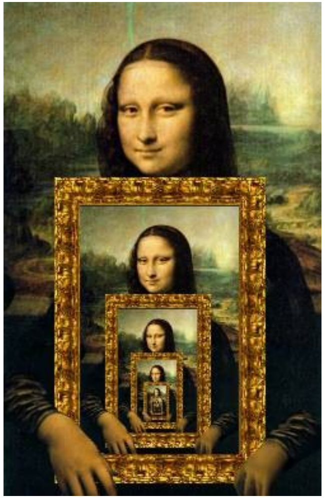
Problem Solving with Computers-I





Let recursion draw you in….

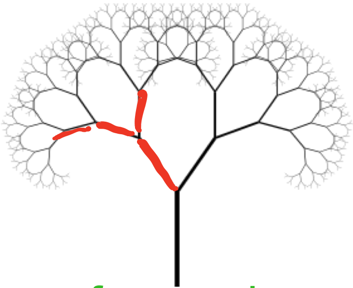
- Recursion occurs when something is described in terms of itself



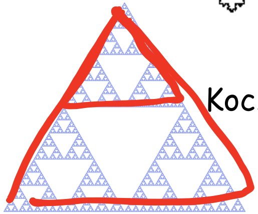
Recursive names

GNU IS NOT UNIX

Fractals



Koch's snowflake

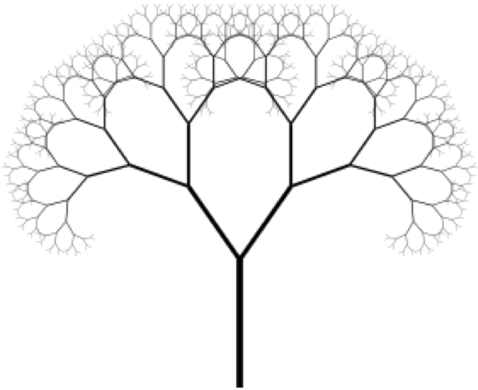


Sierpinski triangle

Visual representations of recursion

Recursion: A way of solving problems in CS

- Solve the simplest case of the problem
- Solve the general case by describing the problem in terms of a smaller version of itself



An everyday example:

To wash the dishes in the sink:

If there are no more dishes

you are done!

else:

Wash the dish on top of the stack

Wash the *remaining* dishes in the sink

Thinking *recursively*

```
N!  =  N * (N-1)! , if  N > 1
    =  1, if N <= 1
```

Recursion == *self*-reference!

$$N! = \underbrace{1 * 2 * 3 * \ldots * (N-1)}_{(N-1)!} * N$$

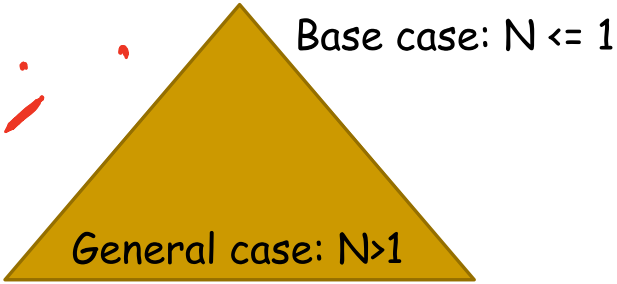
Designing Recursive Functions

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

Base case:

Solution to inputs where the answer is simple to solve

(top of the pyramid)



The pyramid of computation for recursive problems

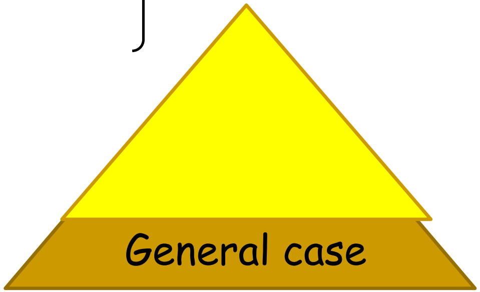
Designing Recursive Functions

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

}
```

Base case

Recursive case



The pyramid of computation for recursive problems

Human: Base case and 1 step

Computer: Everything else

Warning: *this is legal!* (no compiler errors)

```
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!

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

Print the numbers 1 to N recursively

```
void printInorder(int N){

                              //Base case

}
```

Select the appropriate base case:

```
A.   cout<<N<<endl;
B.   if (N == 1){
        cout<<N<<endl;
     }
C.  if (N <= 1){
        return;
    }
D. All of the above are correct
```

no stopping condition (missing return)
would be okay if the rest of the code was placed in an else block as follows:

```
if(N==1){
    cout<<N<<endl;
}else{
    printInOrder(N-1);
    cout<<N<<endl;
}
```

See preferred style on next slide

Print the numbers 1 to N recursively

```
void printInorder(int N){
        if (N<=0) return; //Base case

        __________________ (A)
        printInorder(N-1);
        cout<<N<<endl      (B)
}
```

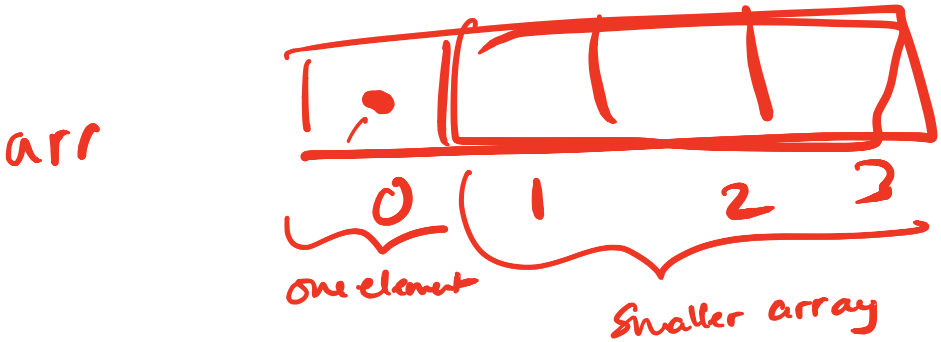
Choose the correct location of this statement:

```
cout<<N<<endl;
```

Tracing recursive code

Function call	output
printInOrder(1);	1
printInOrder(2); Calls printInOrder(1). cout<< 2 <<endl;	1 2
printInOrder(3) Calls printInOrder(2); cout<< 3 <<endl;	1 2 3

A new way of looking at inputs



Arrays:

- Non-recursive description: **a sequence of elements**
- Recursive description: **an element, followed by a smaller array**

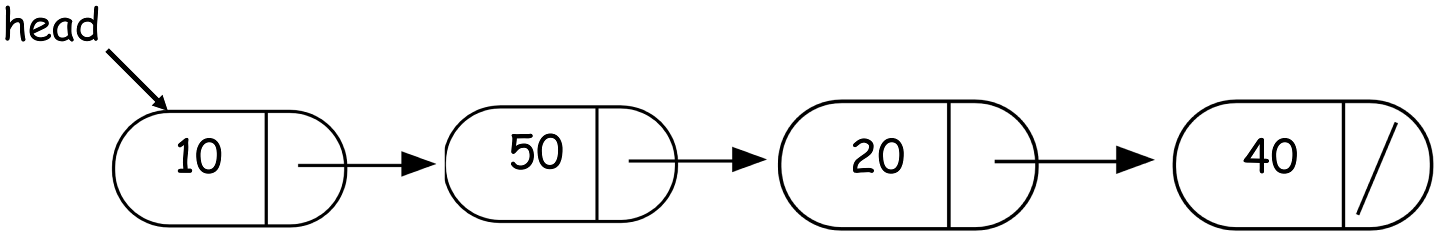
Print all the elements of an array in order

```
void printArray(int arr[], int len){
        if(len <=0) return;
        cout<<arr[0]<<endl;
        printArray(_______, _______);
}
```

Select the arguments to the call to printArray:

A. (arr, len)
B. (arr - 1, len - 1)
C. (arr + 1, len - 1)
D. (arr + 1, len)
E. (arr - 1, len)

Recursive description of a linked list

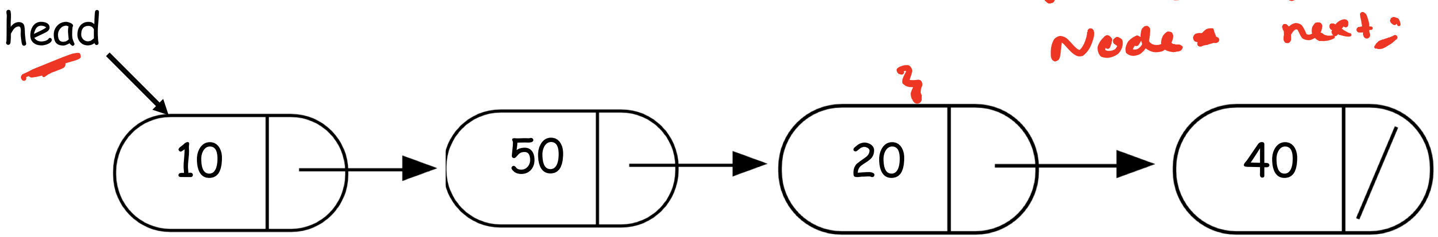


- Non-recursive description of the linked list: **chain of nodes**
- Recursive description of a linked-list: **a node, followed by a smaller linked list**

Recursion to solve problems involving linked-lists

- Recursive description of a linked-list: **a node, followed by a smaller linked list**

struct Node {
int data;
Node* next;
}



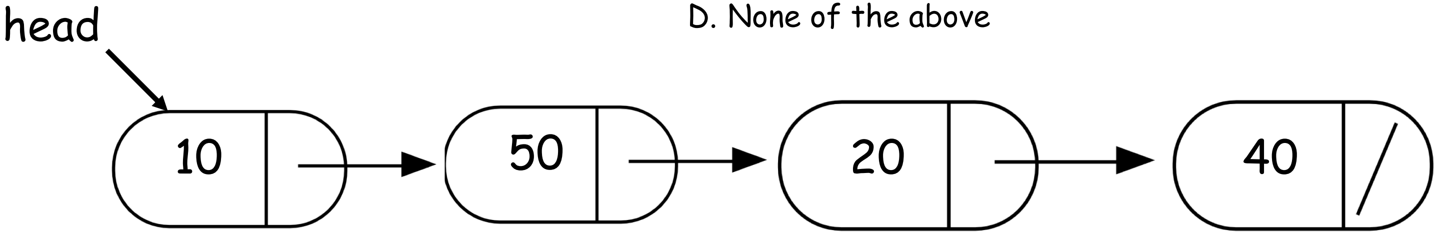
Small group activity (10 minutes)

1. **Write a recursive function to return the sum of the values stored in a linked list**
2. **Share your code with the person sitting next to you and discuss**

What's in a base case?

What happens when we execute this code on the example linked list?

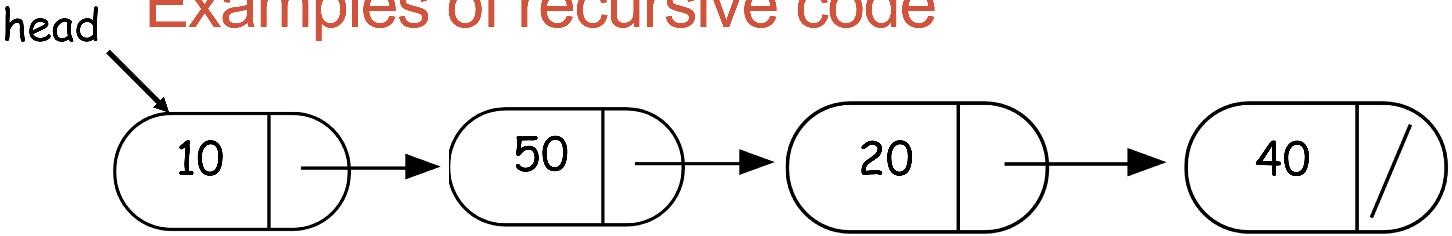
A. Returns the correct sum (120)
B. Program crashes with a segmentation fault (missing base case)
C. Program runs forever
D. None of the above




```
double sumList(Node* head){

    double sum = head->value + sumList(head->next);
    return sum;
}
```

Examples of recursive code




```
double sumList(Node* head){
    if(!head) return 0;
    double sum = head->value + sumList(head->next);
    return sum;
  }
```

Find the min element in a linked list

```
double min(Node* head){
    // Assume the linked list has at least one node
    assert(head);
     // Solve the smallest version of the problem




  }
```

Helper functions

- Sometimes your functions takes an input that is not easy to recurse on
- In that case define a new function with appropriate parameters: This is your helper function
- Call the helper function to perform the recursion

For example

```
double sumLinkedLisr(LinkedList* list){
    return sumList(list->head); //sumList is the helper
    //function that performs the recursion.

}
```

Next time

- More practice with recursion
- Final practice