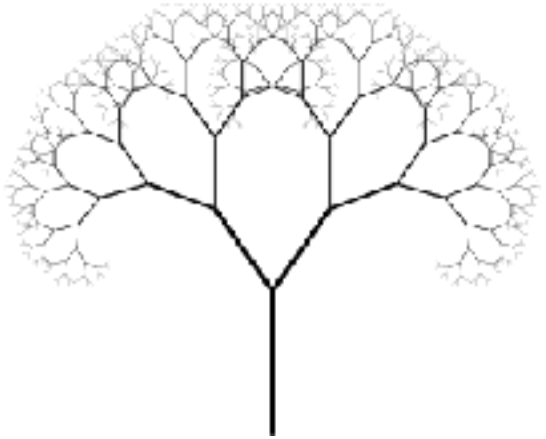
RECURSION, WRAP UP

Problem Solving with Computers-I



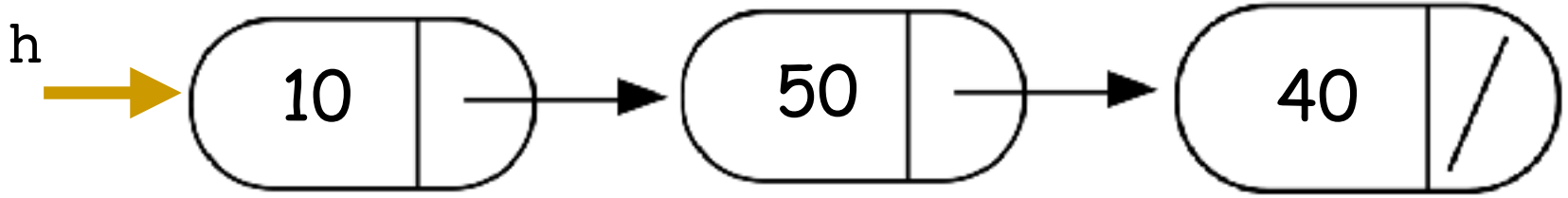
String problems

1. Count the number of vowels in a C string
2. Remove all the spaces from a C++ string

```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```

head

sumRest



Imagine each instance of sumList to be a doll!

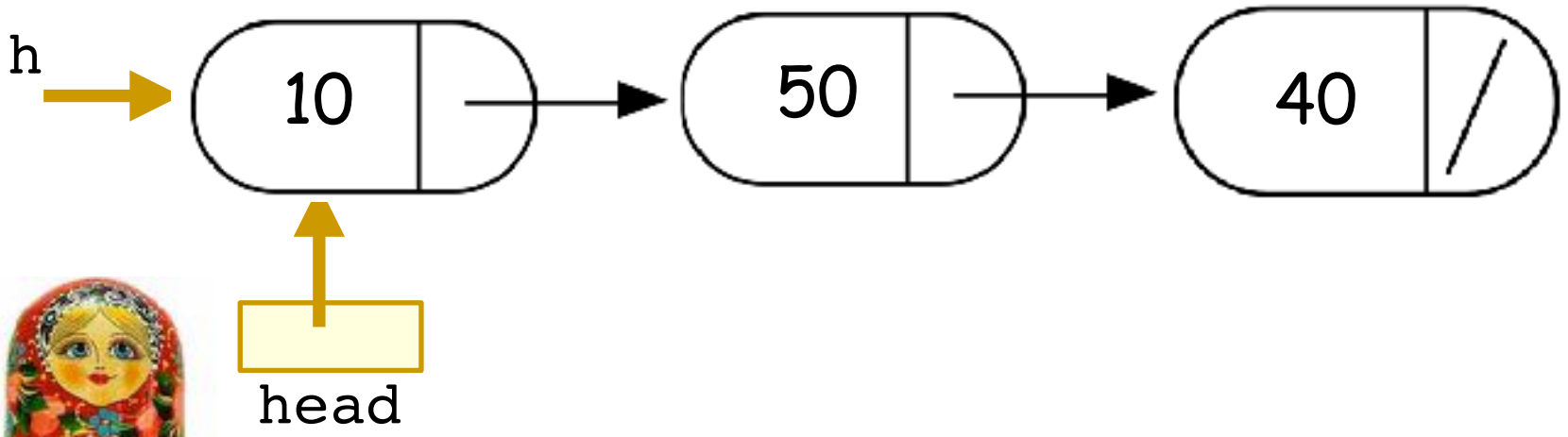
Calling sumList is like creating a new doll.

First call to sumList!

```
double s=sumList(h);
```

```
double sumList(Node* head){
    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```

The turtle tells us which line of code is going to be executed

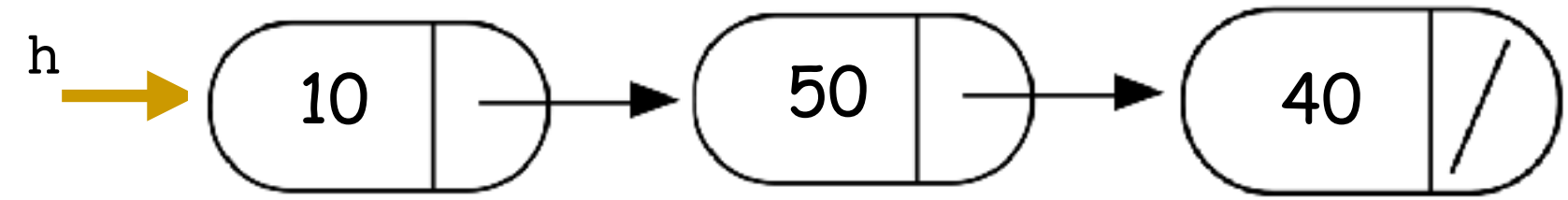


sumList(1)

First call to sumList!

```
double s=sumList(h);
```

```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```



head

?

sumRest

sumList(1)

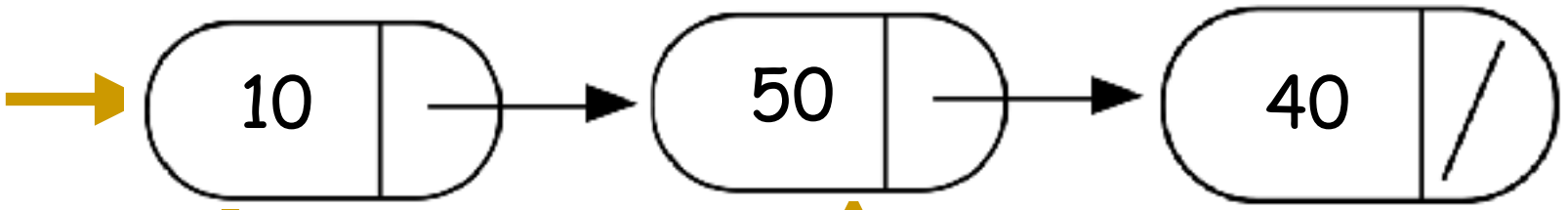
Second call to sumList!

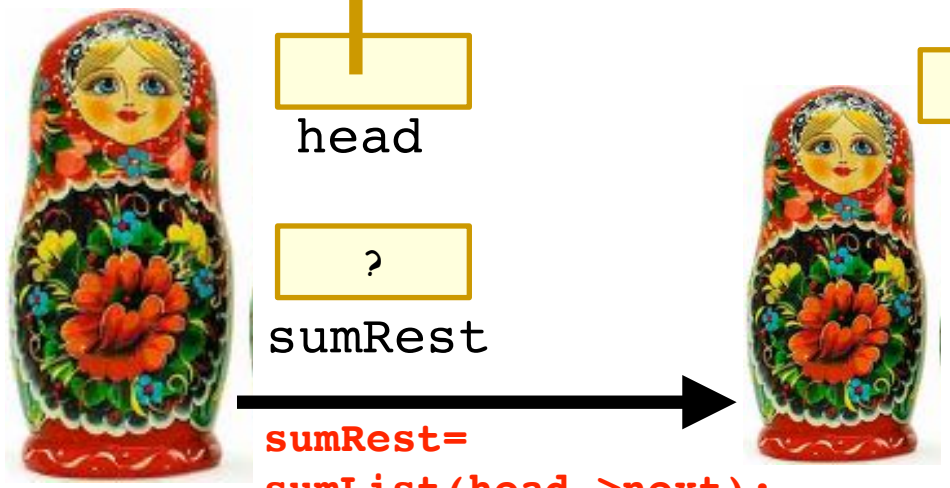
First call to sumList!

```
double s=sumList(h);
```

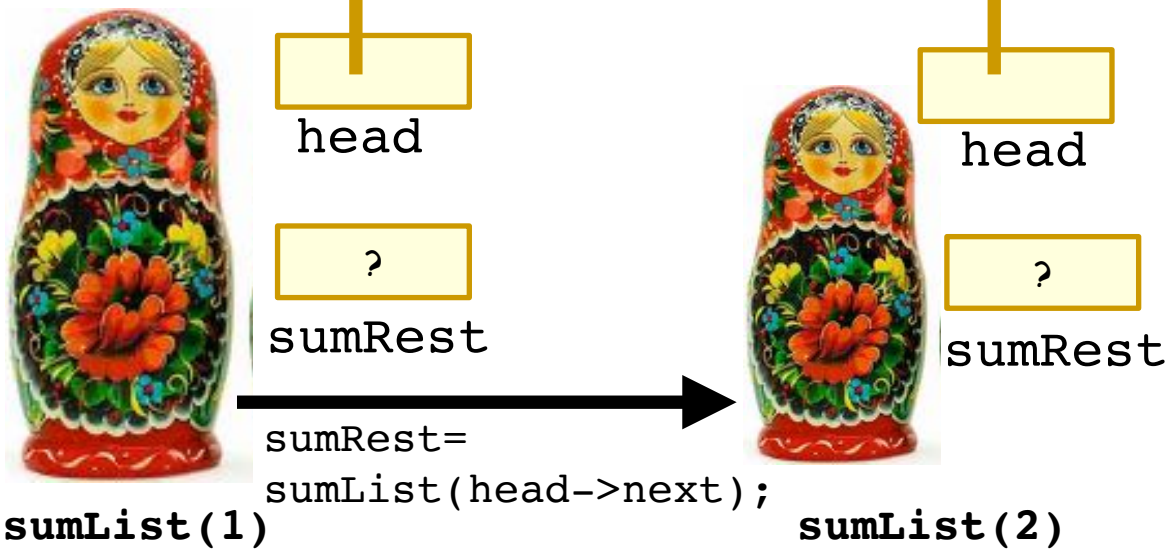
```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```

Turtle is going to execute the first line of sumList(2)



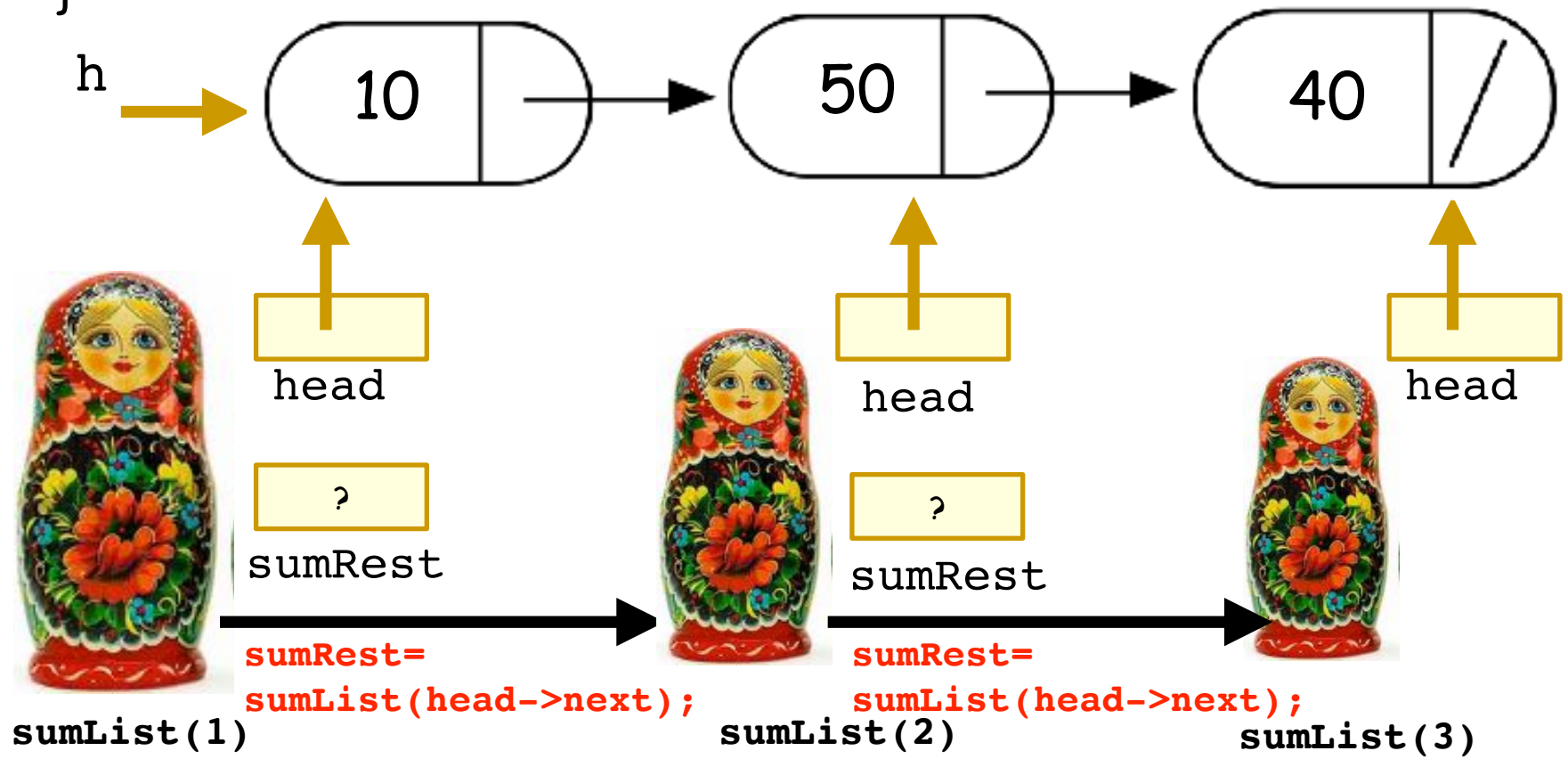


```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```

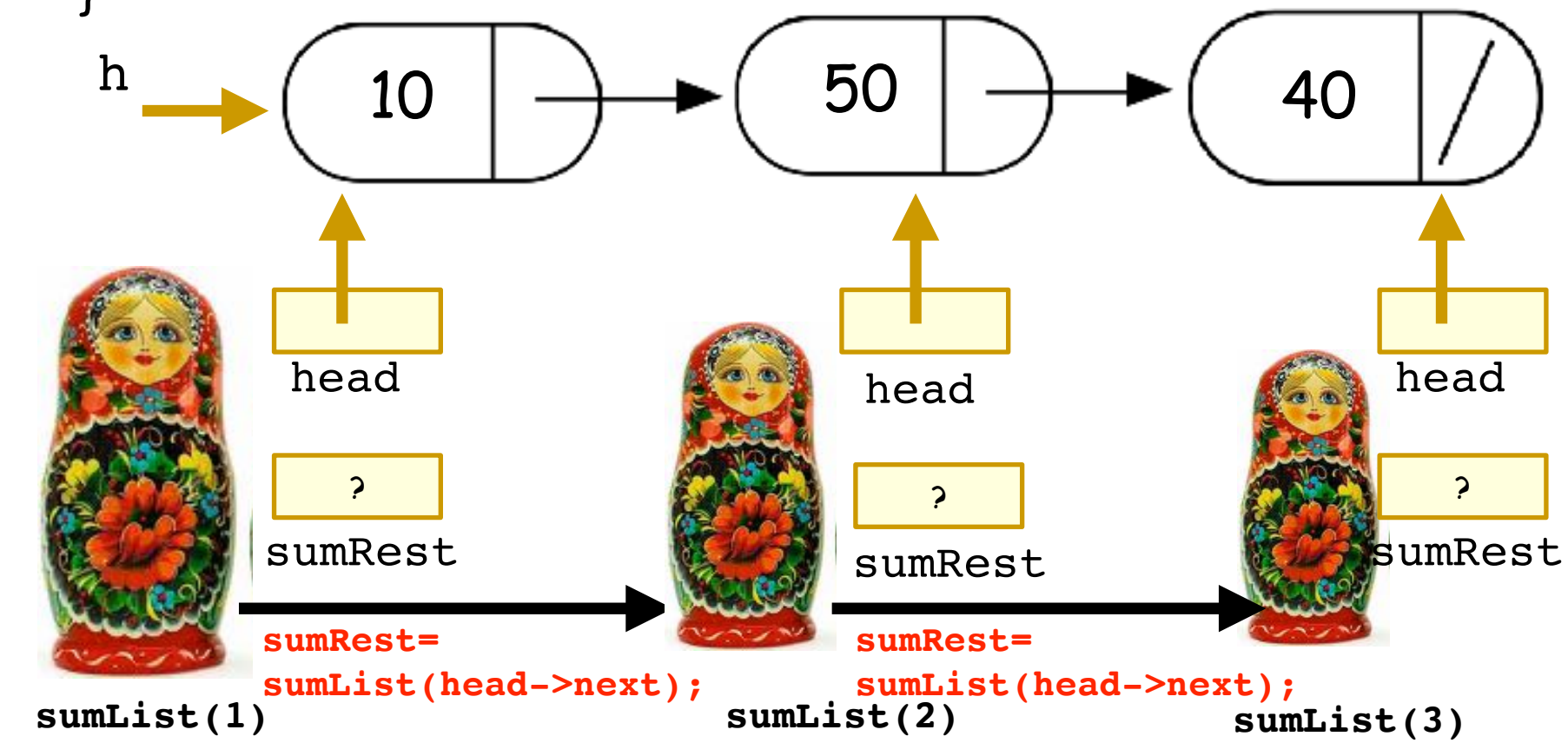


Third call to sumList

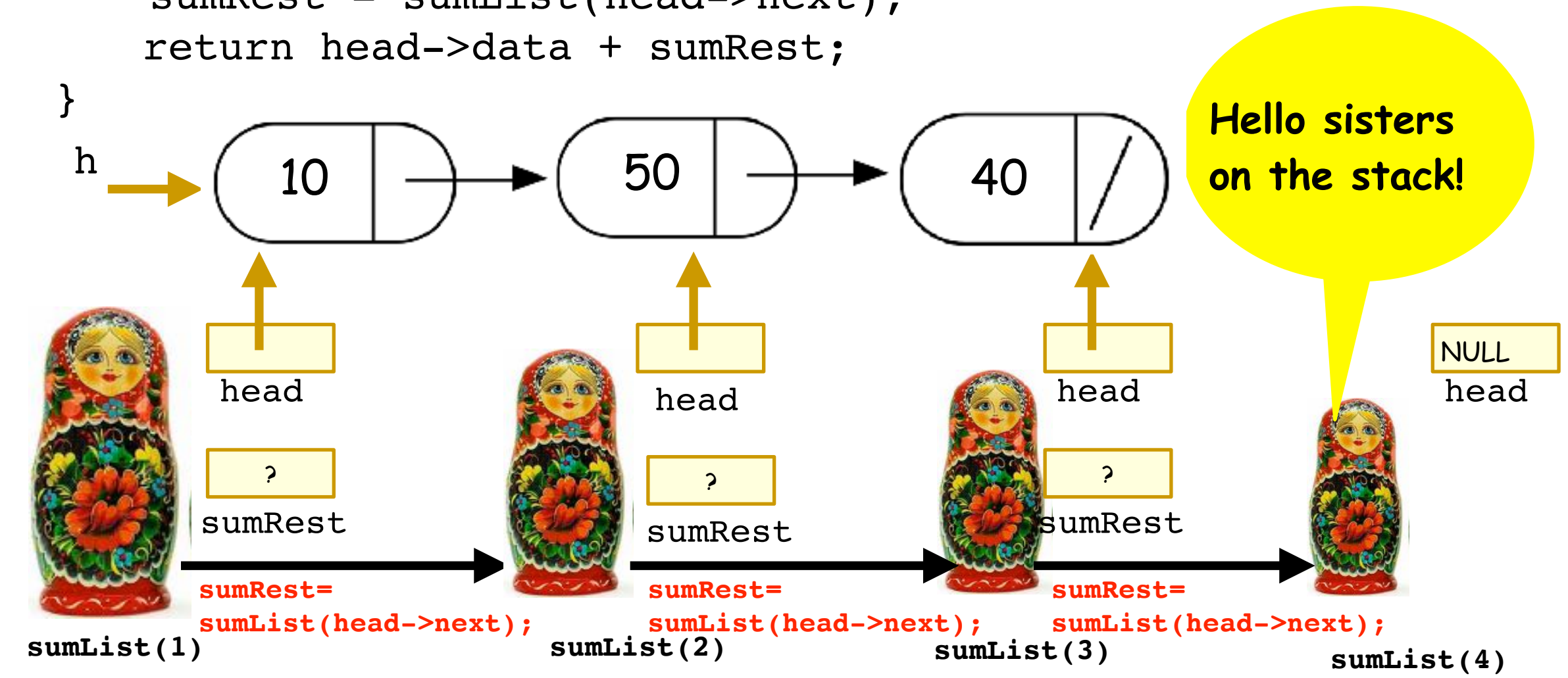
```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```



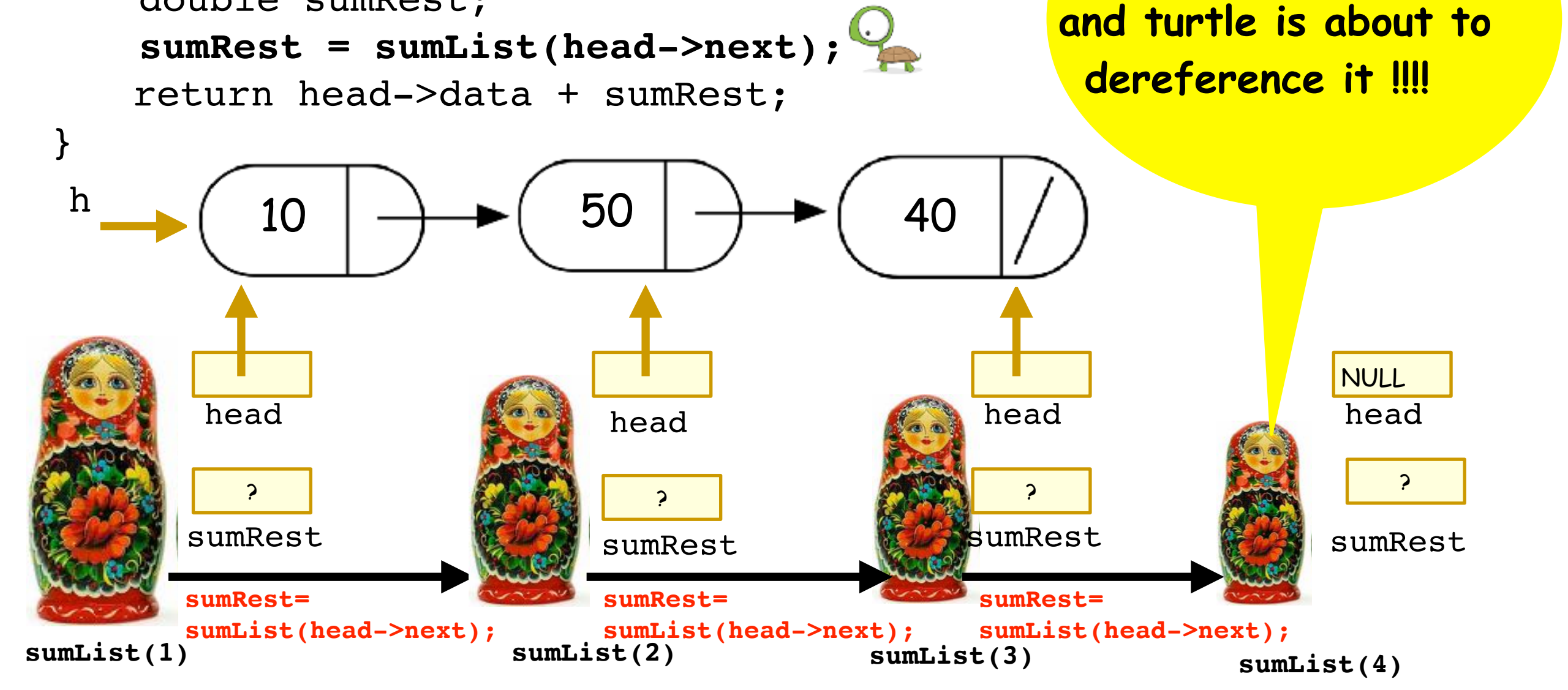
```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```



```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```

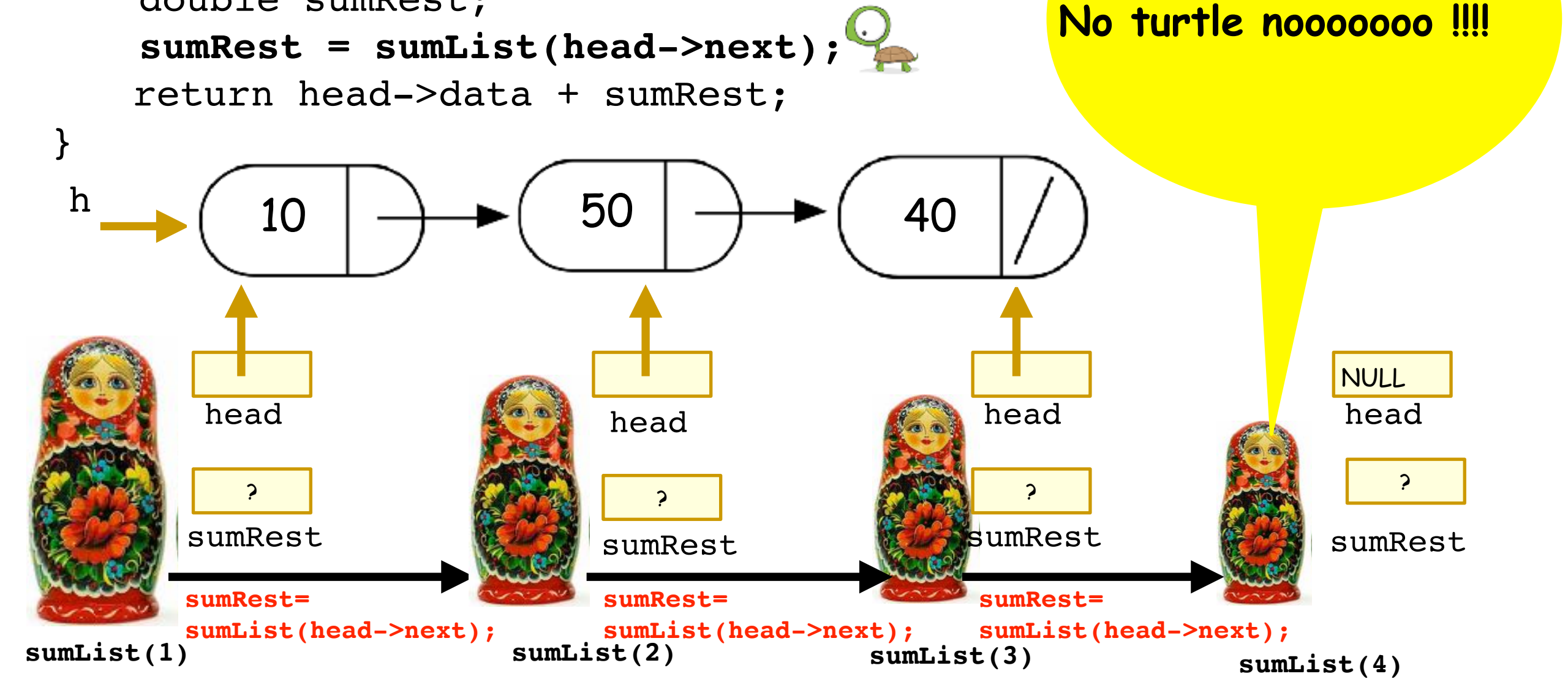


```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```

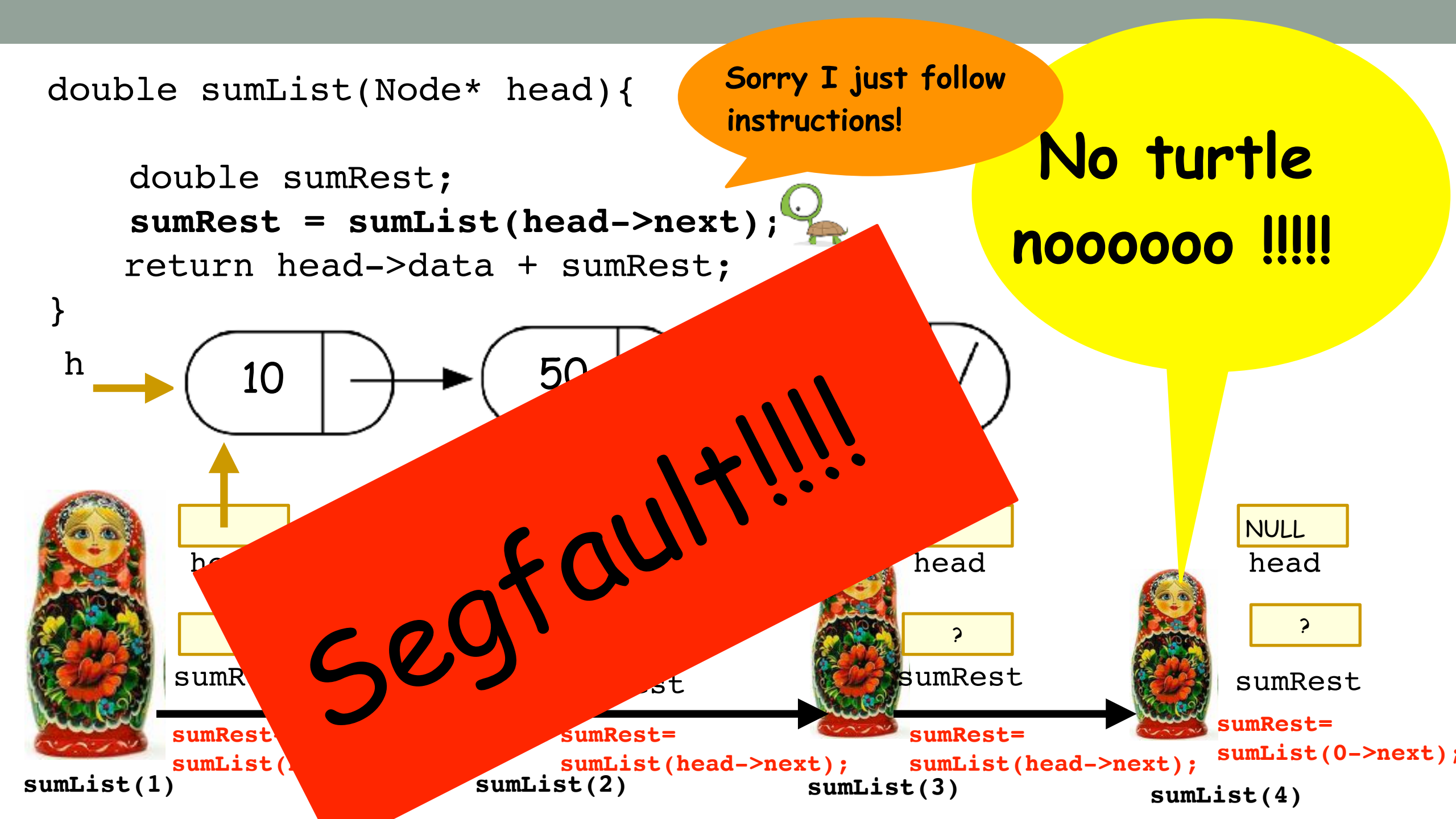


Oops my head is null and turtle is about to dereference it !!!!

```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```



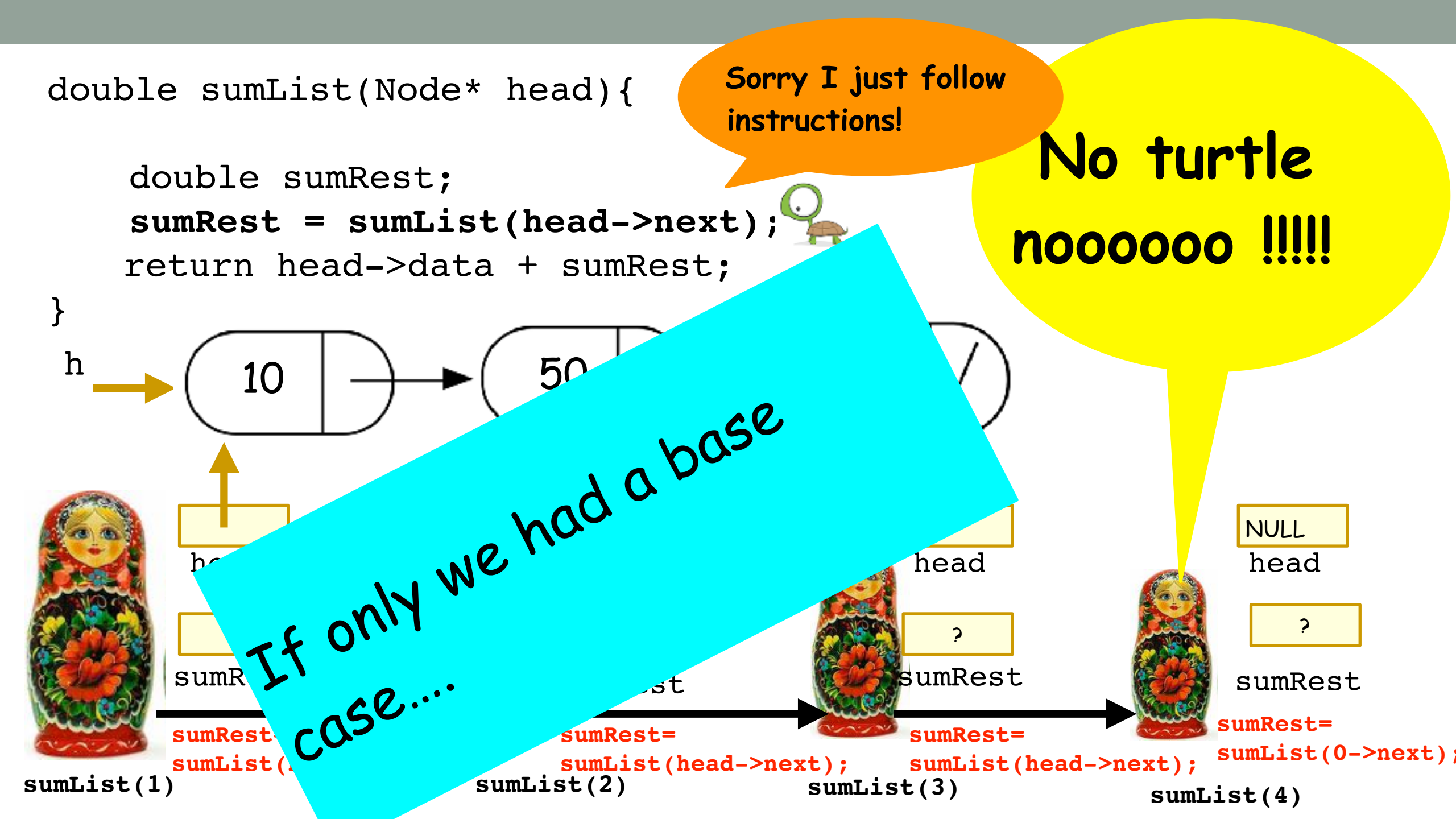
```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```



```
double sumList(Node* head){

    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```

Sorry I just follow instructions!

No turtle noooooo !!!!!

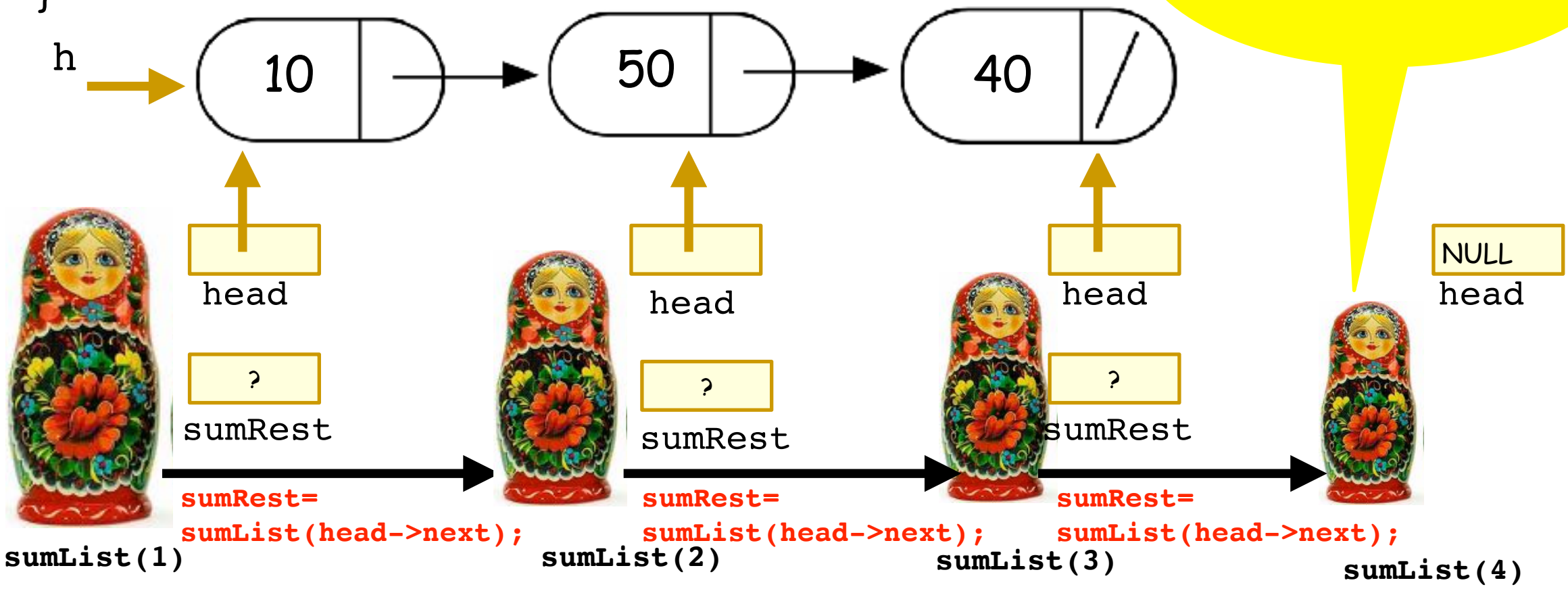


If only we had a base case....

```
double sumList(Node* head){
    if(head==0) return 0;
     double sumRest;
     sumRest = sumList(head->next);
     return head->data + sumRest;
}
```

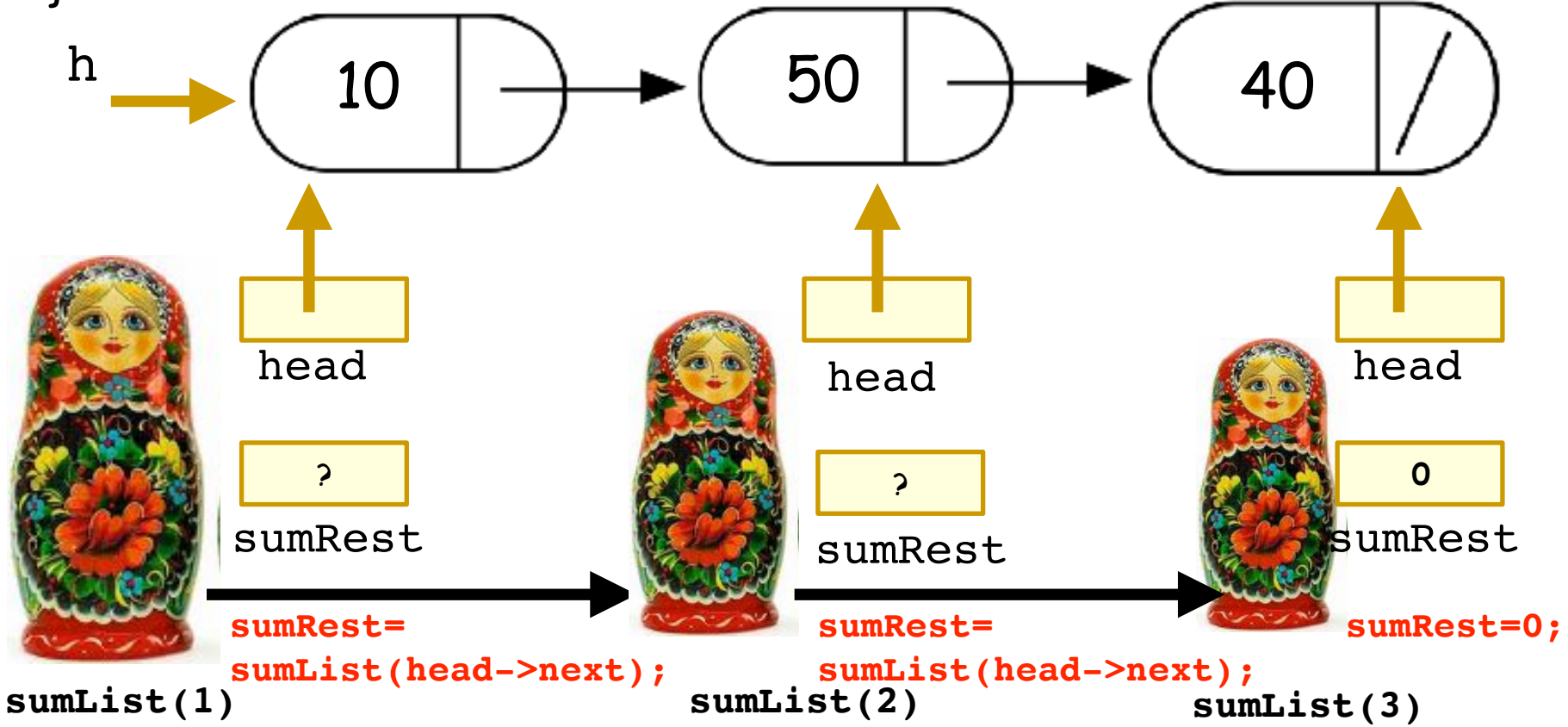
I am really well behaved around base cases :)

return 0;

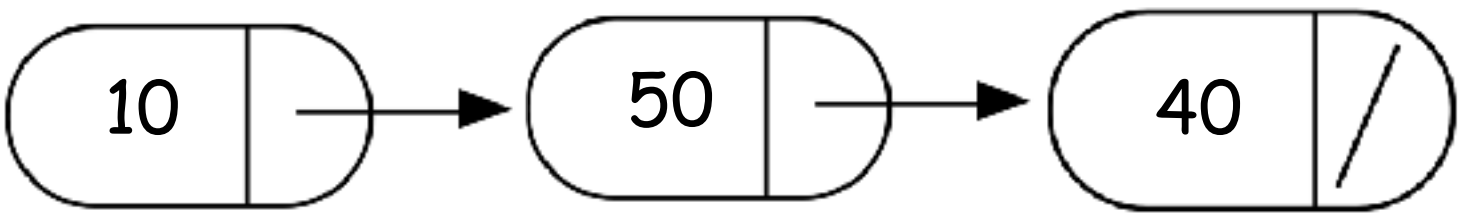


```
double sumList(Node* head){
    if(head==0) return 0;
     double sumRest;
     sumRest = sumList(head->next);
     return head->data + sumRest;
}
```

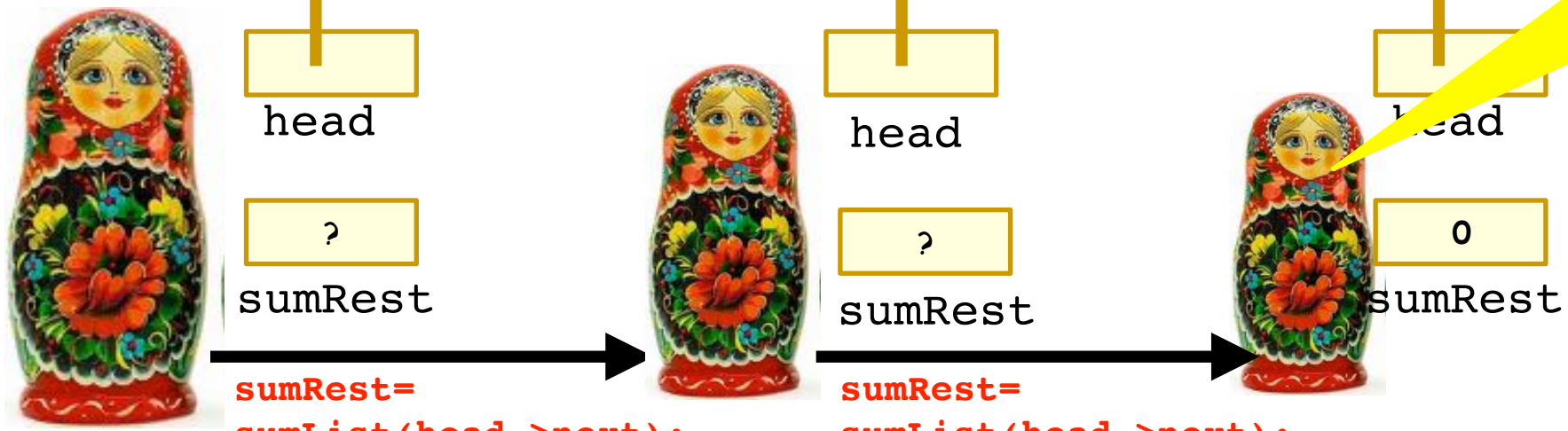
Hello again sumlist(3)! Your younger sister hit the base case.



```
double sumList(Node* head){
    if(head==0) return 0;
     double sumRest;
     sumRest = sumList(head->next);
     return head->data + sumRest;
}
```

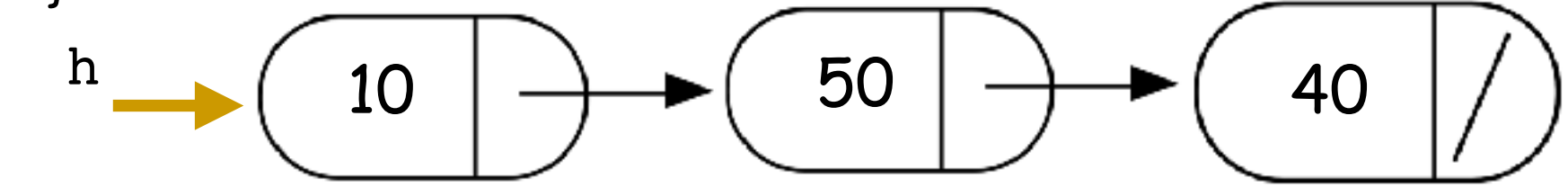


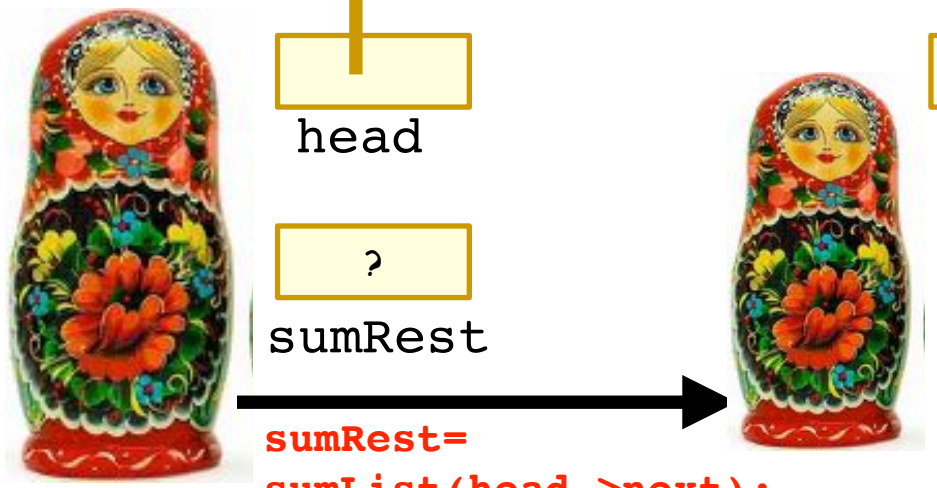
return 40+0;



```
double sumList(Node* head){
    if(head==0) return 0;
     double sumRest;
     sumRest = sumList(head->next);
     return head->data + sumRest;
}
```

Hello again Sumlist(2)! Your younger sister returned 40.

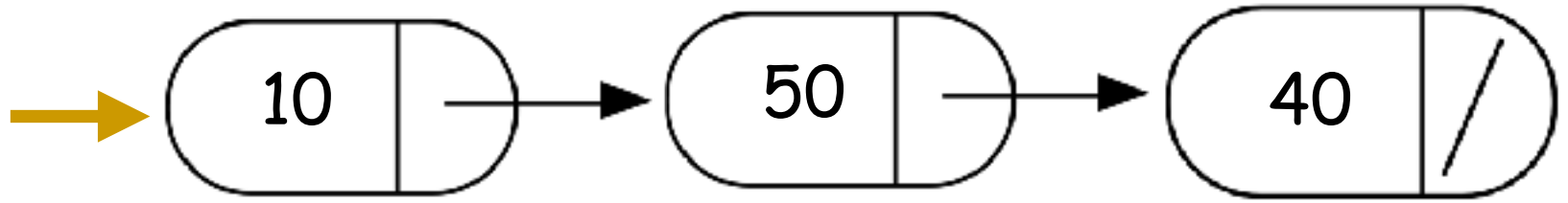





```
return head->data + sumRest;
```

```
double sumList(Node* head){
    if(head==0) return 0;
     double sumRest;
     sumRest = sumList(head->next);
     return head->data + sumRest;
}
```

Any last words, sumList(2)?



head

?

sumRest

sumRest=
sumList(head->next);

sumList(1)

head

40

sumRest

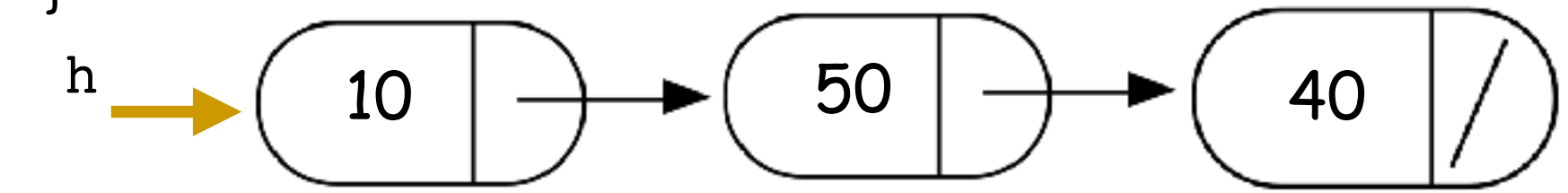
sumList(2)

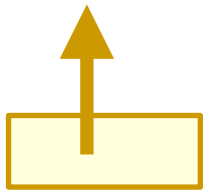
return 50+40;

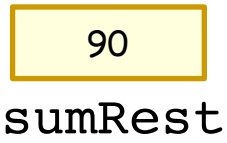
return head->data + sumRest;

```
double sumList(Node* head){
    if(head==0) return 0;
    double sumRest;
    sumRest = sumList(head->next);
    return head->data + sumRest;
}
```

Hello again sumList(1)!
Your sisters are no longer on the stack, here is your 90, store it safely!





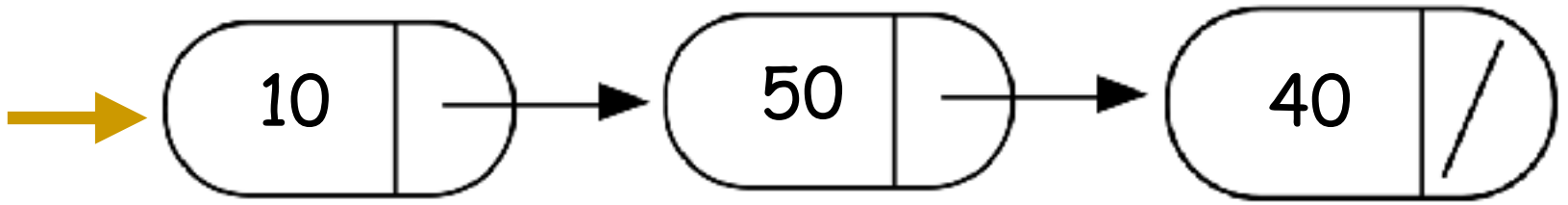


return head->data + sumRest;

sumList(1)

```
double sumList(Node* head){
    if(head==0) return 0;
     double sumRest;
     sumRest = sumList(head->next);
     return head->data + sumRest;
}
```

How did I get into this line of work, so many goodbyes make me want to cry.



head

90

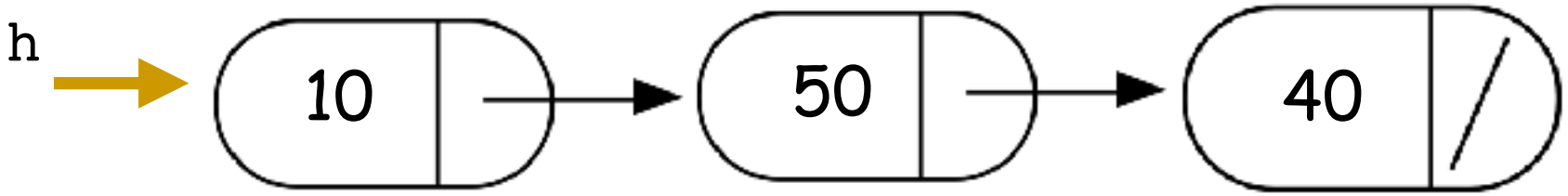
sumRest

return 10+90;

B'bye and thanks for all the computation!

sumList(1)

```
double sumList(Node* head){
    if(head==0) return 0;
     double sumRest;
     sumRest = sumList(head->next);
     return head->data + sumRest;
}
```



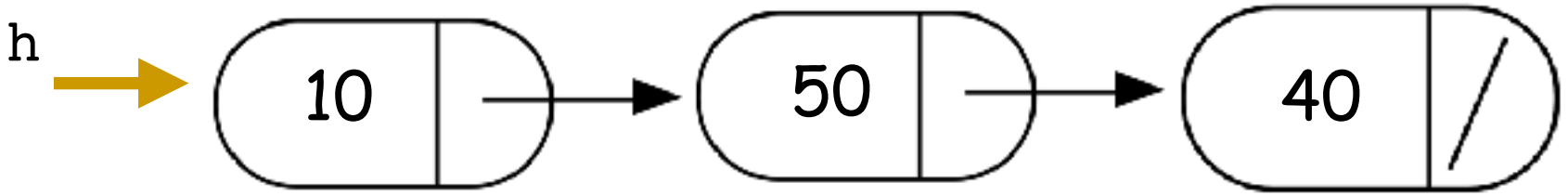
You have
no idea how many calls I had
to make to sum this list!

```
double s=sumList(h);
```

```
double sumList(Node* head){
    if(head==0) return 0;
     double sumRest;
     sumRest = sumList(head);
     return head->data + sumRest;
}
```

What happens when we call sumList on the example linked list?

A. Returns the correct sum (100)
B. Program crashes with a segmentation fault
C. Program runs for a while, then crashes
D. None of the above



double s=sumList(h);

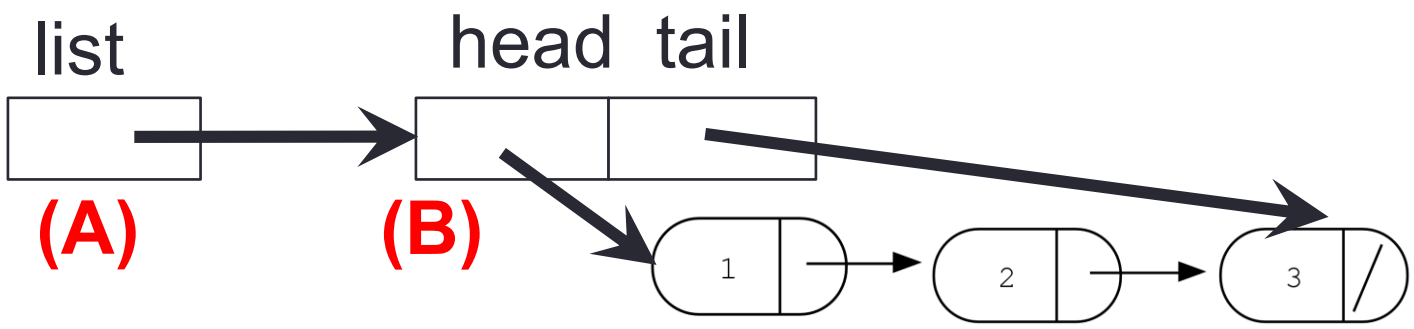
More Recursion Examples

- Calculate the nth element of the Fibonacci sequence
  - Why is the recursive solution inefficient?
- Calculate a^b when b is a non-negative int
- Binary tree sum of nodes
  - This is a more complicated example involving a data structure that we don't cover in this class. I won't test you on this!

Deleting the list

int freeLinkedList(LinkedList * list){…}

Which data objects are deleted by the statement: delete list;



(C) All nodes of the linked list

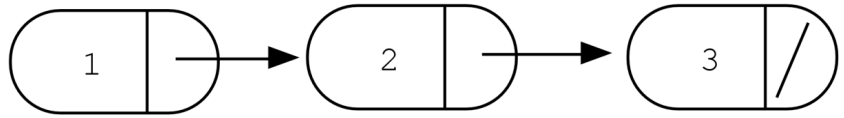
(D) B and C

(E) All of the above

Does this result in a memory leak?

Recursion on lists: delete a value recursively

void deleteNodeRecursive(LinkedList *list, int value)

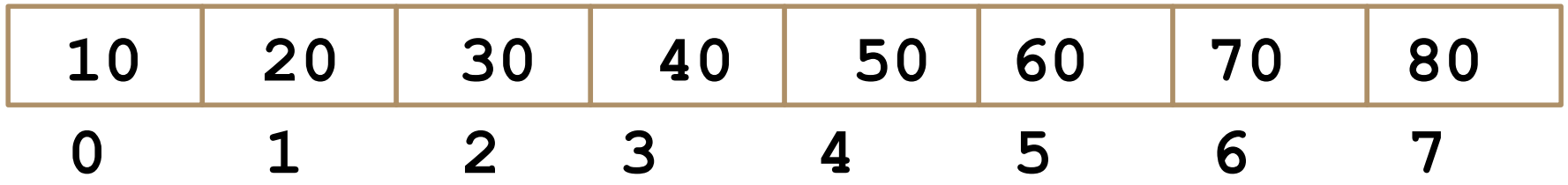


Node* deleteNodeRecursiveHelper(Node *head, int value)

why does this need to return a Node*?

Recall the steps towards a recursive solution

Searching for a value in a sorted array



Binary search!

Start in the middle (make a guess), and keep halving your search space as you update your guess with new information.

Find the square root of a number

Same concept!

Guess somewhere between 0 and the number, and keep on updating your guess (and halving the search space). You will eventually approach the answer.

How do you check if your guess was too big or too small?

The remaining slides are about concepts that I will not test you on. You'll need to know them for CS 24, though!

Binary/Hex Arithmetic

- Calculate $101_2 + 001_2$
- Calculate $10101101_2 + 10001111_2$
  - What if our ints were only 8 bits long?
- Calculate $2A_{16} + B8_{16}$
- What about negative numbers?!

Bitwise operations

- and (&)
- or (|)
- not (~)
- exclusive or (xor) (^)
- shift left and right (<< and >>)

Bitwise AND `&` [edit]

bit a	bit b	`a & b` (a AND b)
0	0	0
0	1	0
1	0	0
1	1	1

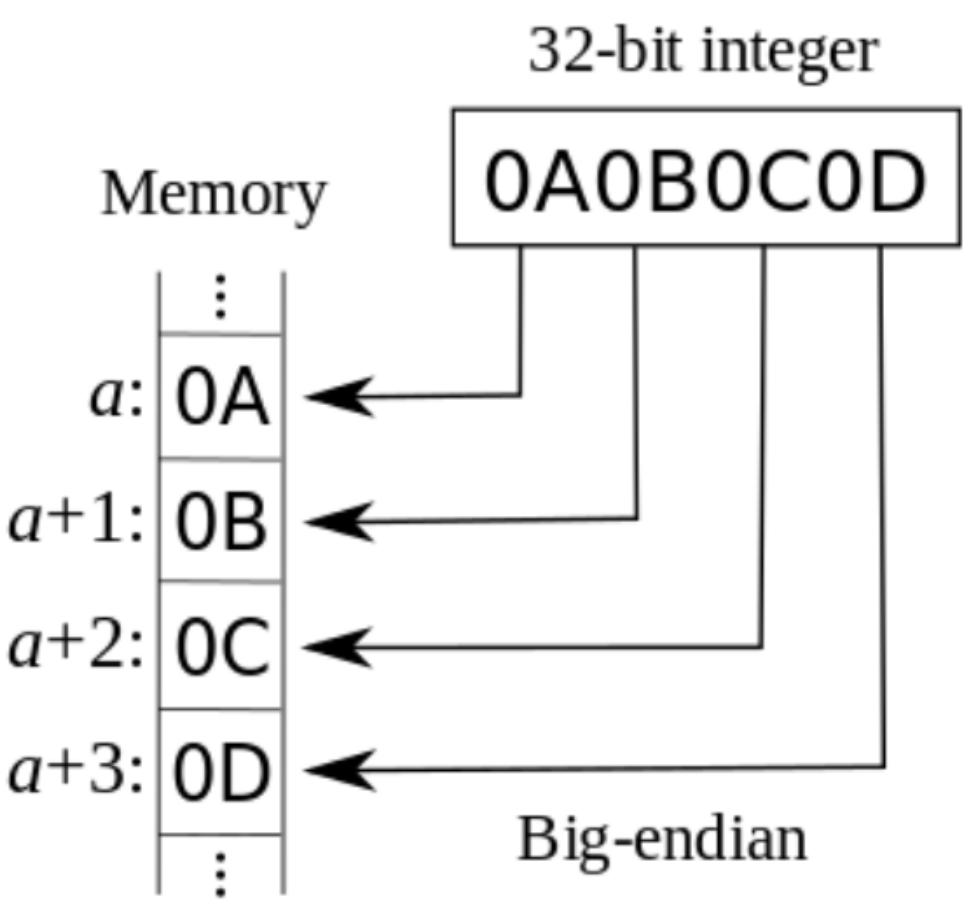
Bitwise OR `|` [edit]

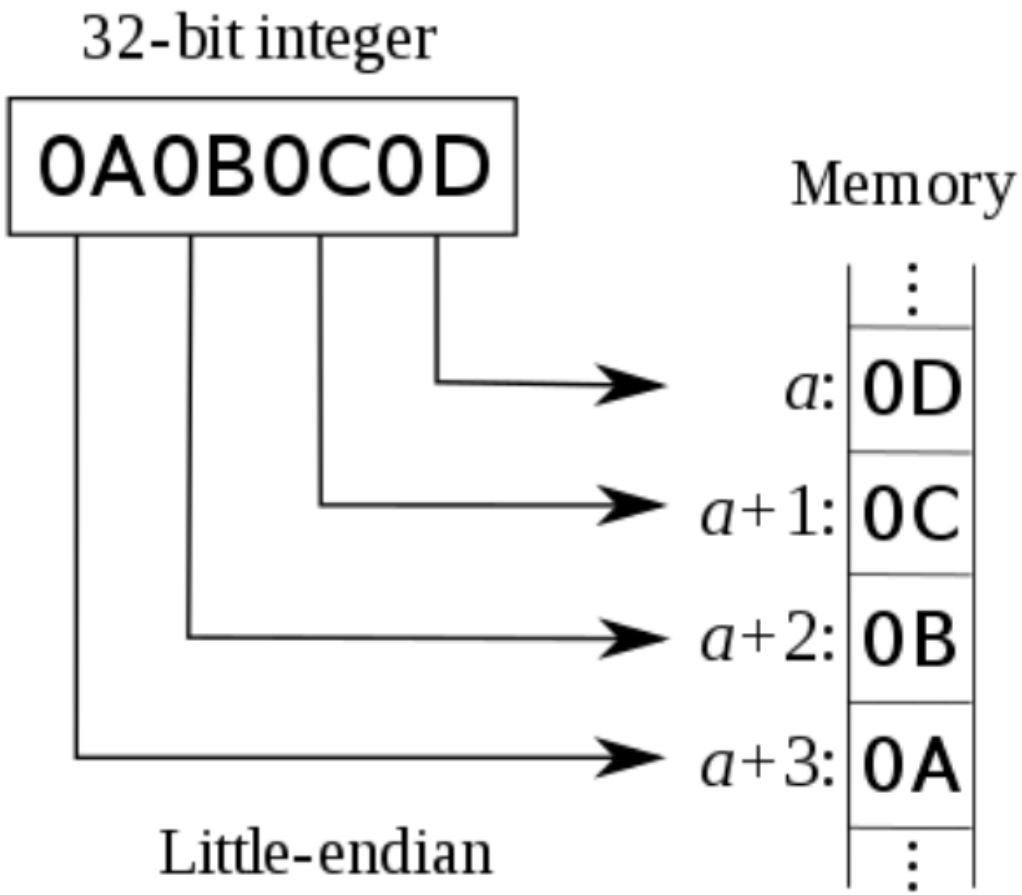
bit a	bit b	a | b (a OR b)
0	0	0
0	1	1
1	0	1
1	1	1

Bitwise XOR `^` [edit]

bit a	bit b	`a ^ b` (a XOR b)
0	0	0
0	1	1
1	0	1
1	1	0

Endianness


32-bit integer
0A0B0C0D
Memory
a: 0A
a+1: 0B
a+2: 0C
a+3: 0D
Big-endian


32-bit integer
0A0B0C0D
Memory
a: 0D
a+1: 0C
a+2: 0B
a+3: 0A
Little-endian

Some comic relief…

HTTP://XKCD.COM/1296/