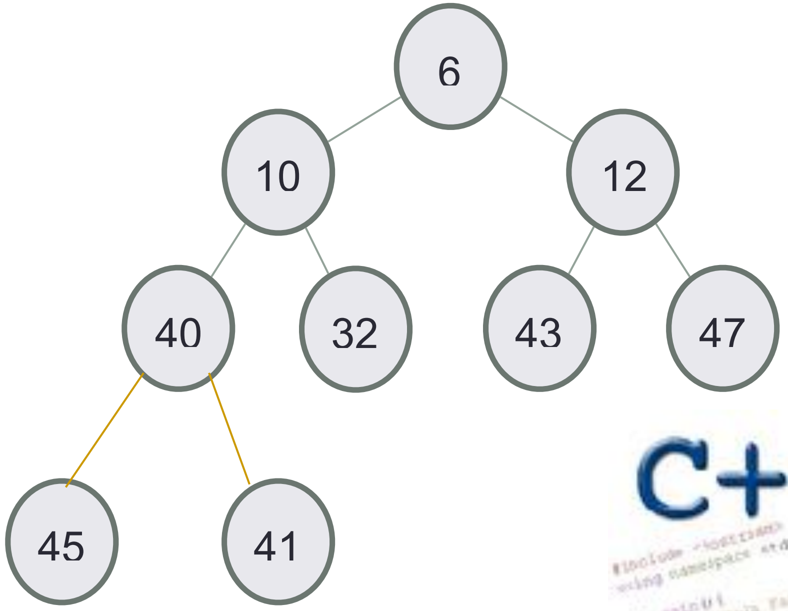
RECURSION

Problem Solving with Computers-II



Let recursion draw you in….

- Many problems in Computer Science have a recursive structure…
- Identify the “recursive structure” in these pictures by describing them

Why is recursion important in Computer Science

- Tool for solving problems (recursive algorithms)
- Solution is simply a recursive description of the problem
- Elegant (short and concise) algorithms
- Example of a recursive algorithm:

To wash the dishes in the sink:

Wash the dish on top of the stack

If there are no more dishes

you are done!

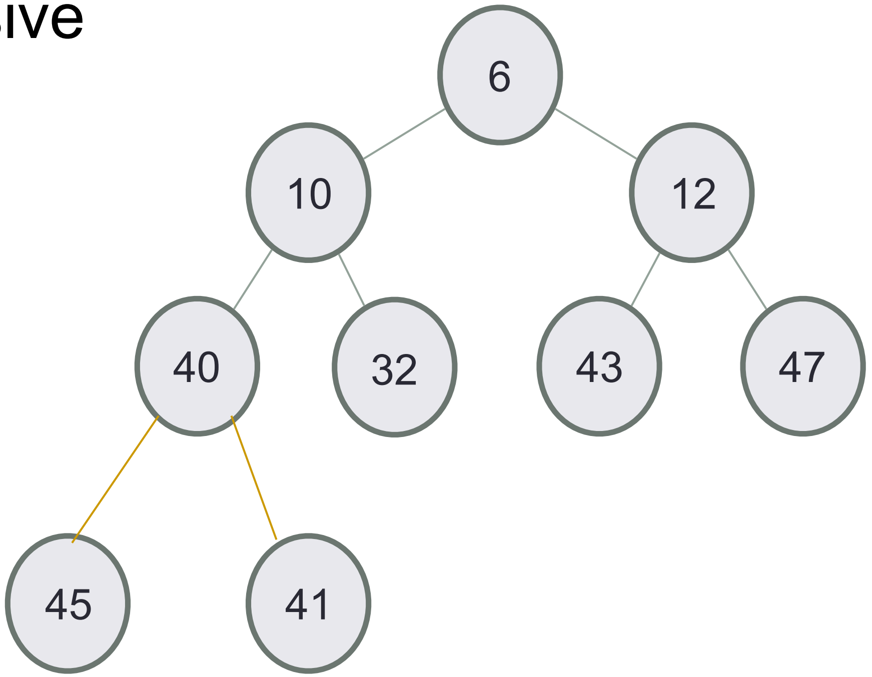
Else:

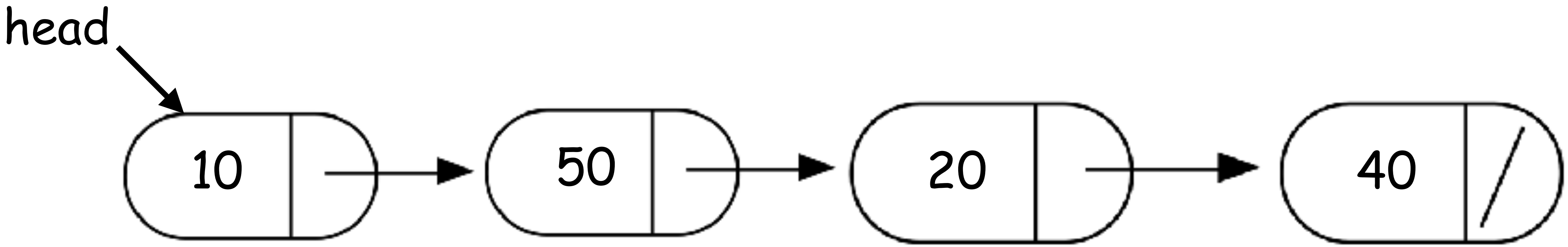
Wash the *remaining* dishes in the sink

Examples from Computer Science

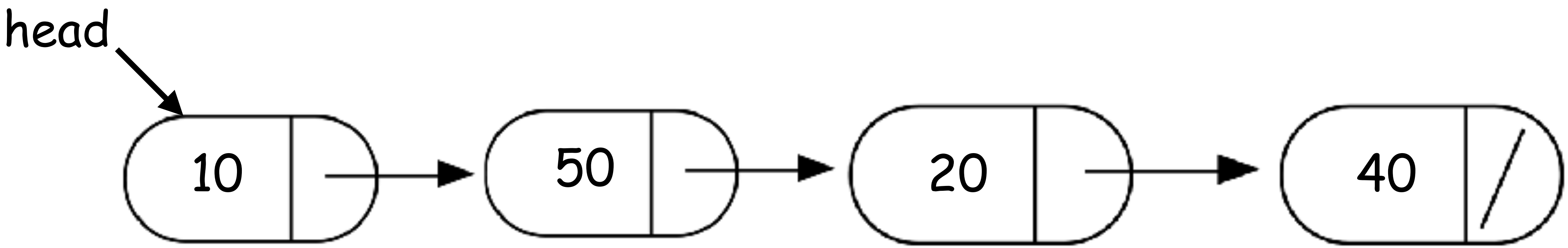
Ask questions about data structures that have a recursive structure like linked lists and trees:

- Find the sum of all the elements in this tree
- Print all the elements in the tree
- Count the number of elements in this tree





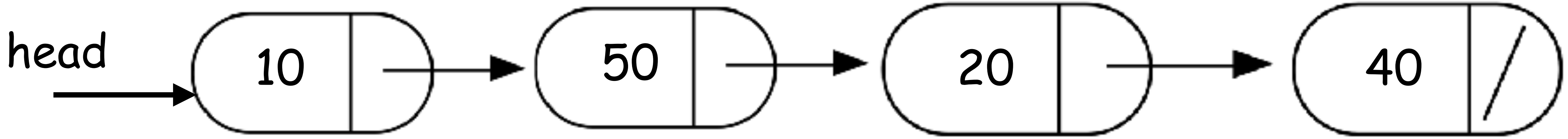
Recursive description of a linked list



- A non-recursive description of the linked list:
  A linked list is a chain of nodes

- A recursive description of a linked-list:
  A linked list is a node, followed by a smaller linked list

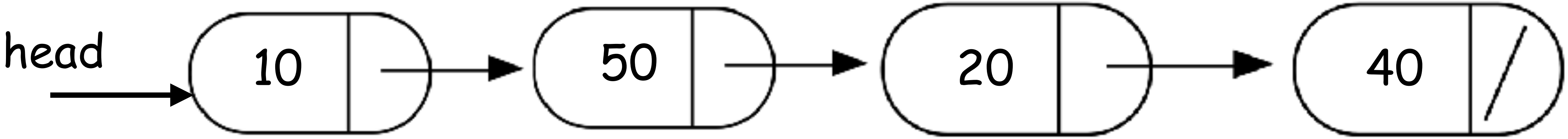
Sum the elements in a linked list



Sum of the elements in the linked list:

    If the linked list is empty,
      return 0
    else
      return Value of the first node + Sum the elements in the *rest* of the list

Search for an element in a linked list

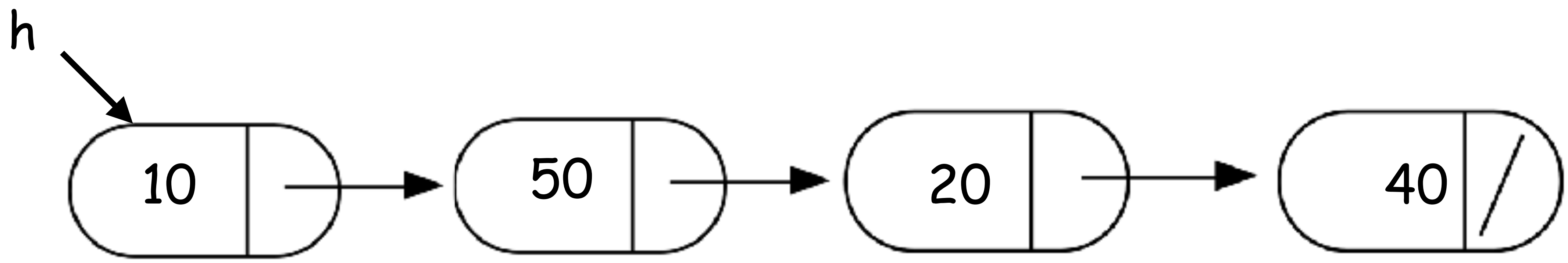


Search for a given value in the linked list:

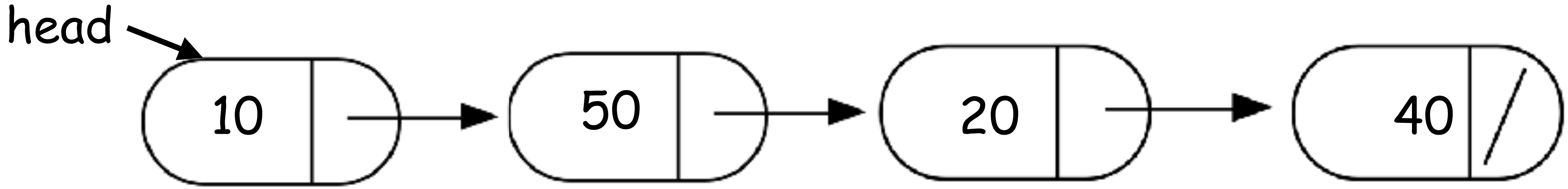
If the value of the first node == given value
    return true
else
    Search for the given value in the *rest* of the list

The base case

```
int IntList::search(Node* h, int value){
    // Solve the smallest version of the problem
    // BASE CASE!!
   if(!h) return false;




 }
```




```
int IntList::search(Node* h, int value){

   // BASE CASE!!
   if(!h) return false;

   // RECURSIVE CASE:
   if (h->value == value)
       return true;
   return search(h->next, value);
  }
```




```
int IntList::search(Node* h, int value){

    // BASE CASE!!
    if(!h) return false;

    // RECURSIVE CASE:
    if (h->value == value)
        return true;
    search(h->next, value);

}
```

What is the output of

cout<<search(head, 50);

A. Segmentation fault
B. Program runs forever
C. Prints true or 1 to screen
D. Prints nothing to screen
E. None of the above

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

```
bool IntList::search(int value){

   return search(head, value);
    //helper function that performs the recursion.

}
```

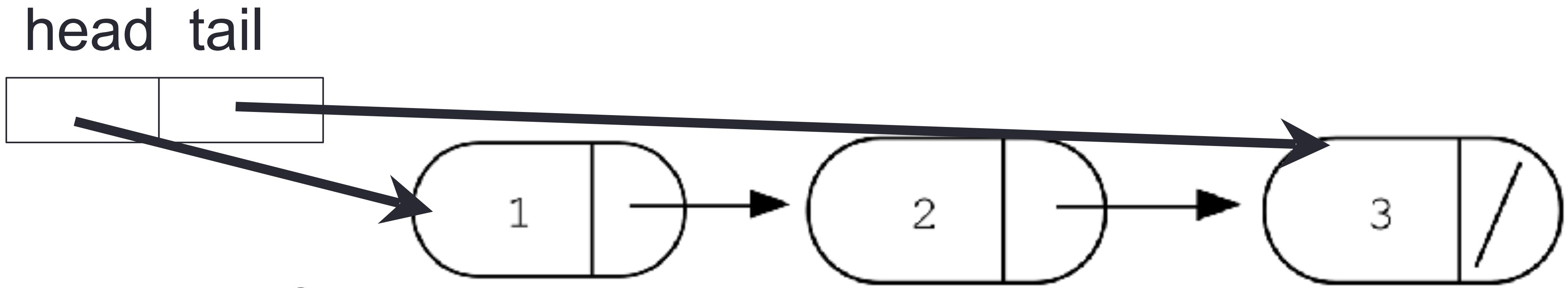
Recursive deconstructors

```
LinkedList::~LinkedList(){
    delete head;
}
```

```
class Node {
    public:
        int info;
        Node *next;
};
```

Which of the following objects are deleted when the deconstructor of Linked-list is called?

(A)



(B): only the first node

(C): A and B

(D): All the nodes of the linked list

(E): A and D

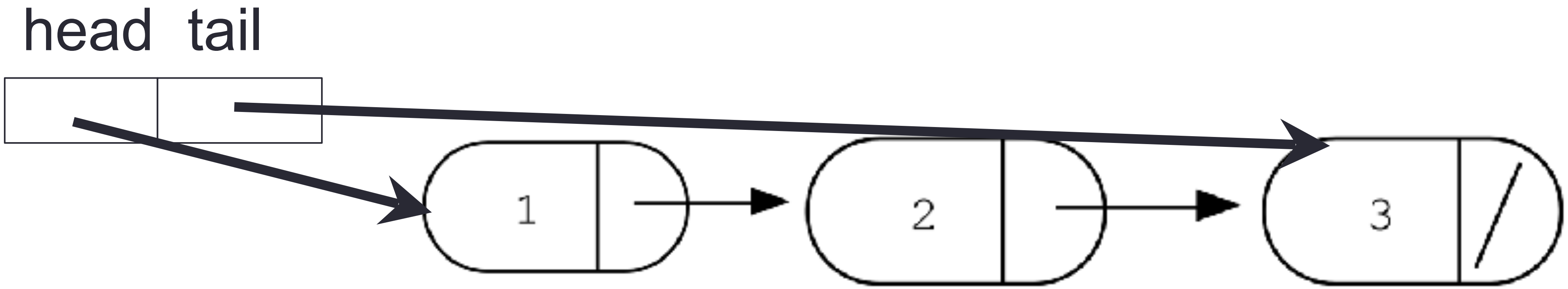
Recursive deconstructors

```
LinkedList::~LinkedList(){
   delete head;
}
```

```
Node::~Node(){
   delete next;
}
```

Which of the following objects are deleted when the deconstructor of Linked-list is called?

(A)



(B): All the nodes in the linked-list

(C): A and B

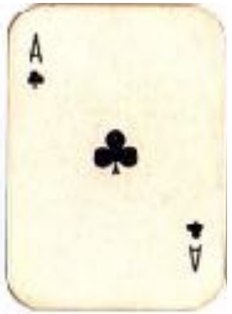
(D): Program crashes with a segmentation fault

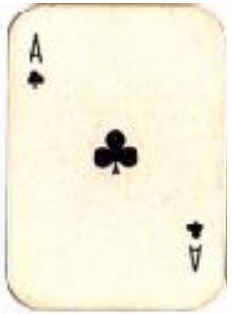
(E): None of the above

How is PA02 going?

A. Done
B. Completed designing my classes but haven’t implemented them yet
C. I understand how to approach the PA, haven’t designed by classes yet
D. I don’t quite understand how to approach the assignment
E. Haven’t read it yet

PA02






Performance questions

- How efficient is a particular algorithm?
  - **CPU time usage (Running time complexity)**
  - Memory usage
  - Disk usage
  - Network usage

- Why does this matter?
  - Computers are getting faster, so is this really important?
  - Data sets are getting larger – does this impact running times?

How can we measure time efficiency of algorithms?

- One way is to measure the absolute running time
- Pros? Cons?

```
clock_t t;
t = clock();

//Your algo

t = clock() - t;
```

Which implementation is significantly faster?

```
function F(n){
    if(n == 1) return 1
    if(n == 2) return 1
return F(n-1) + F(n-2)
}
```

```
function F(n){
 Create an array fib[1..n]
 fib[1] = 1
 fib[2] = 1
 for i = 3 to n:
    fib[i] = fib[i-1] + fib[i-2]
 return fib[n]
}
```

A. *Recursive* algorithm

B. *Iterative* algorithm

C. *Both are almost equally fast*

A better question: How does the running time scale as a function of input size

```
function F(n){
     if(n == 1) return 1
     if(n == 2) return 1
return F(n-1) + F(n-2)
}
```

```
function F(n){
 Create an array fib[1..n]
 fib[1] = 1
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 for i = 3 to n:
    fib[i] = fib[i-1] + fib[i-2]
 return fib[n]
}
```

The “right” question is: How does the running time scale?

E.g. How long does it take to compute F(200)?

….let’s say on….

NEC Earth Simulator

Can perform up to 40 trillion operations per second.

The running time of the recursive implementation

The Earth simulator needs 2^{95} seconds for F_{200}.

Time in seconds	Interpretation
2^{10}	17 minutes
2^{20}	12 days
2^{30}	32 years
2^{40}	cave paintings
2^{70}	The big bang!

```
function F(n){
    if(n == 1) return 1
    if(n == 2) return 1
return F(n-1) + F(n-2)
}
```

Let's try calculating F_{200} using the iterative algorithm on my laptop…..

Next time

- More on Running time analysis