Recursion

You will learn what recursion is as well as how simple recursive programs work

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What Is Recursion?

"the determination of a succession of elements by operation on one or more preceding elements according to a rule or formula involving a finite number of steps" (Merriam-Webster online)

What This Really Means

Breaking a problem down into a series of steps. The final step is reached when some basic condition is satisfied. The solution for each step is used to solve the previous step. The solution for all the steps together form the solution to the whole problem.

Definition For Philosophy

"…state of mind of the wise man; practical wisdom…" [1]

See Metaphysics

1 The New Webster Encyclopedic Dictionary of the English Language

Metaphysics

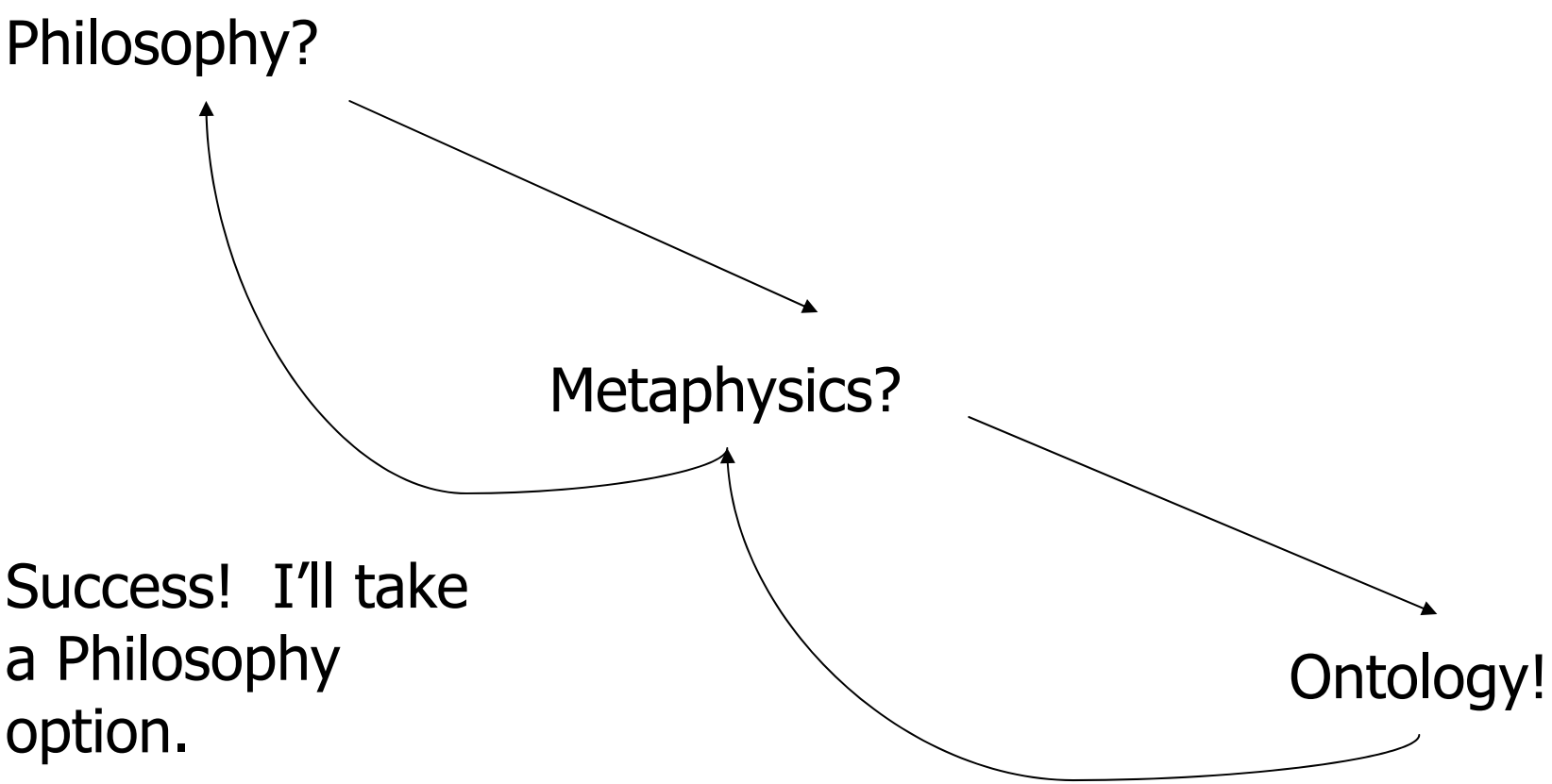
"…know the ultimate grounds of being or what it is that really exists, embracing both psychology and ***ontology***." [2]

2 The New Webster Encyclopedic Dictionary of the English Language

Result Of Lookup , Possibility One: Success

- I know what Ontology means!

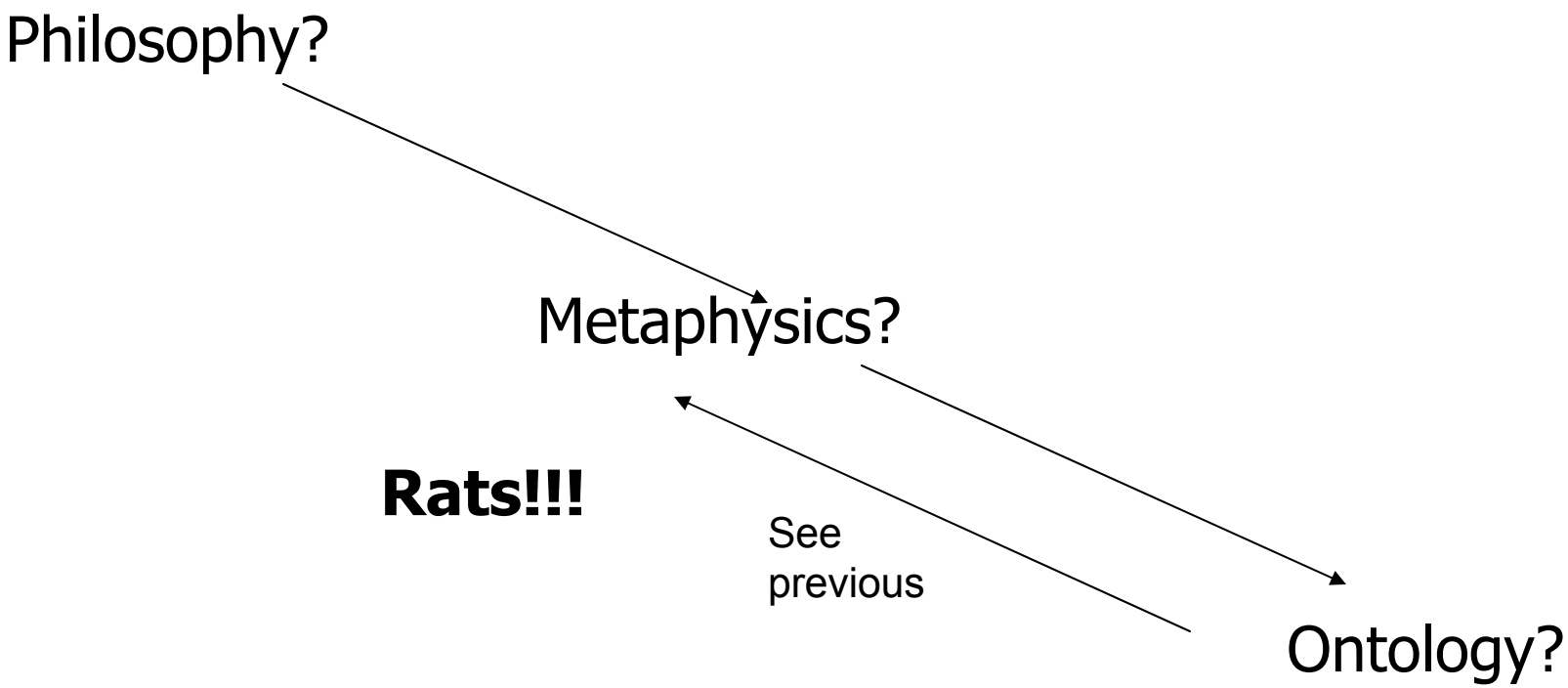
Result Of Lookup, Possibility One



Result Of Lookup, Possibility Two: Failure

- Lookups loop back.

Result Of Lookup, Possibility Two



Ontology

"…equivalent to metaphysics."[3]

3 The New Webster Encyclopedic Dictionary of the English Language

Wav file from "The Simpsons"

Result Of Lookup, Possibility Three: Failure

- You've looked up everything and still don't know the definition!

Looking Up A Word

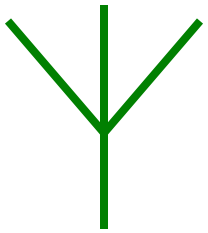
if (you completely understand a definition) then

    return to previous definition (using the definition that's understood)

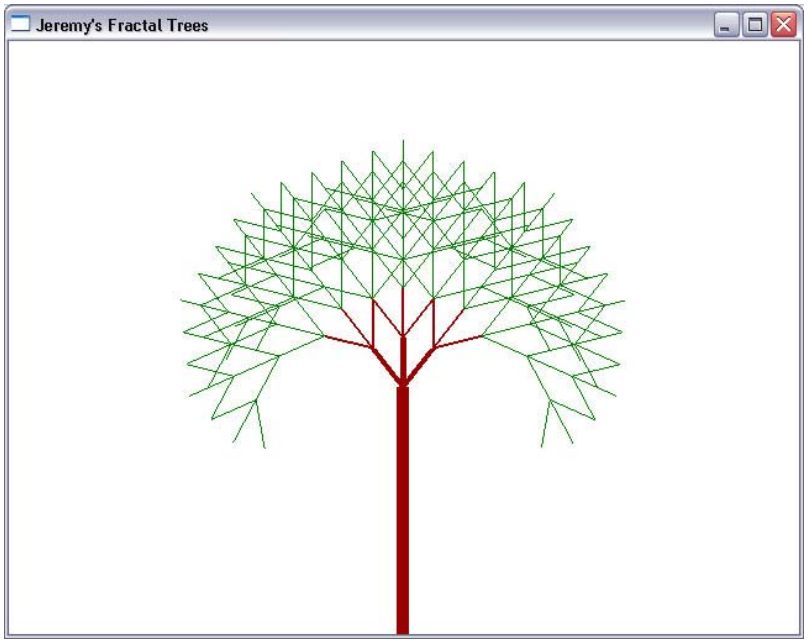
else

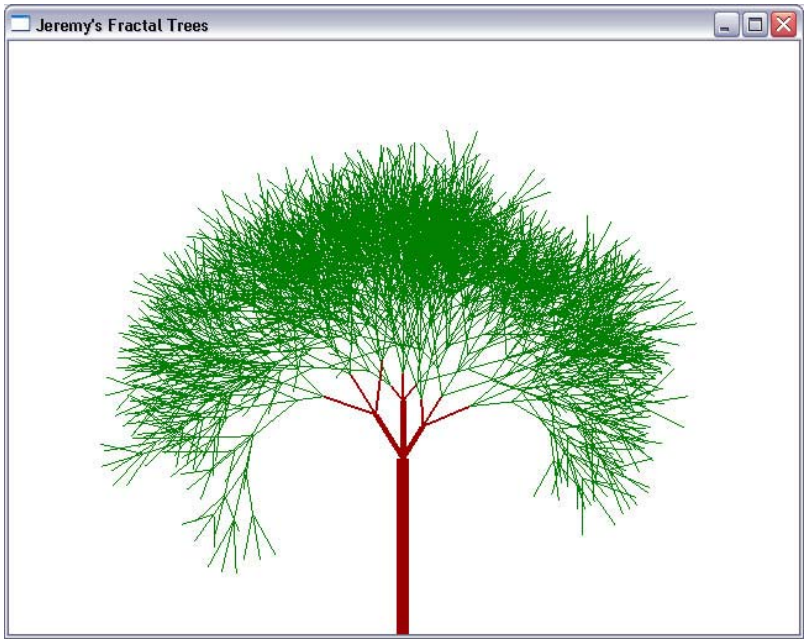
    lookup (unknown word(s))

Graphics That Employ Recursion



Produce a picture by repeating a pattern





Images from http://www.csis.gvsu.edu/~marzkaj/CS367/project1.htm

Graphics That Employ Recursion (2)

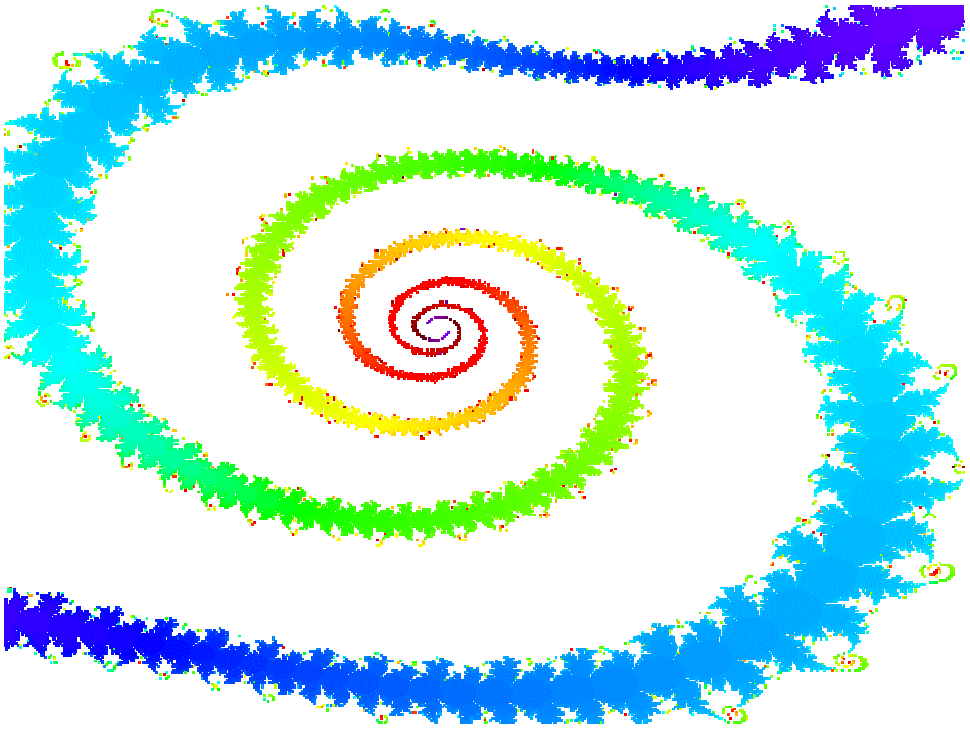
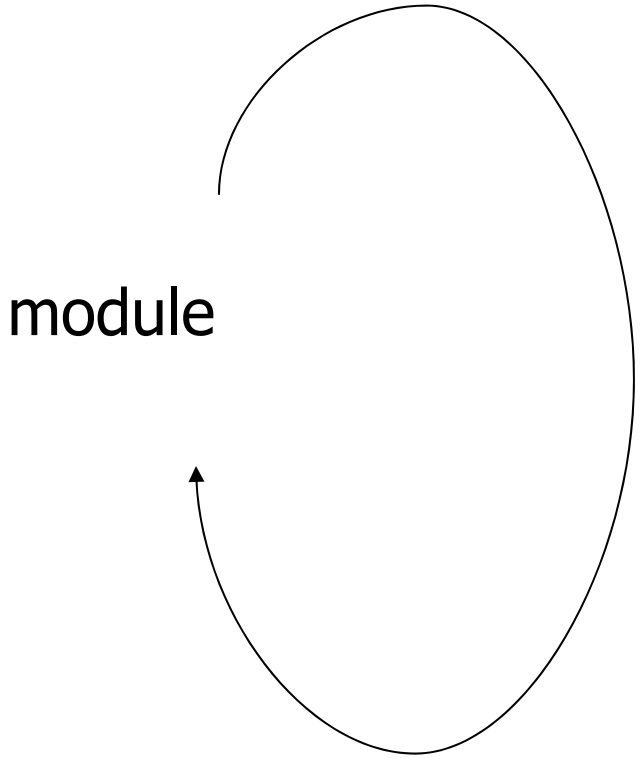


Image from http://www.efg2.com/Lab/FractalsAndChaos/

Recursion In Programming

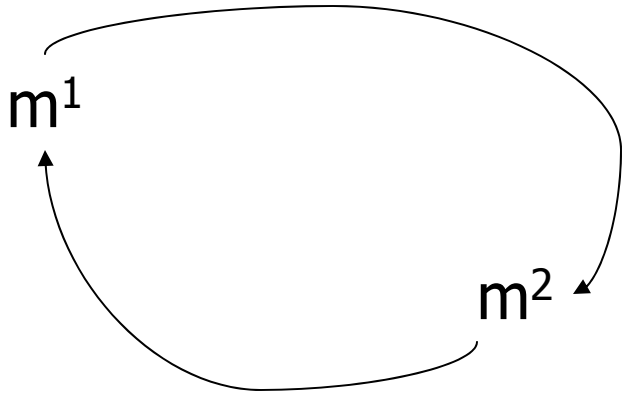
"A programming technique whereby a function or procedure calls itself either directly or indirectly."

Direct Call

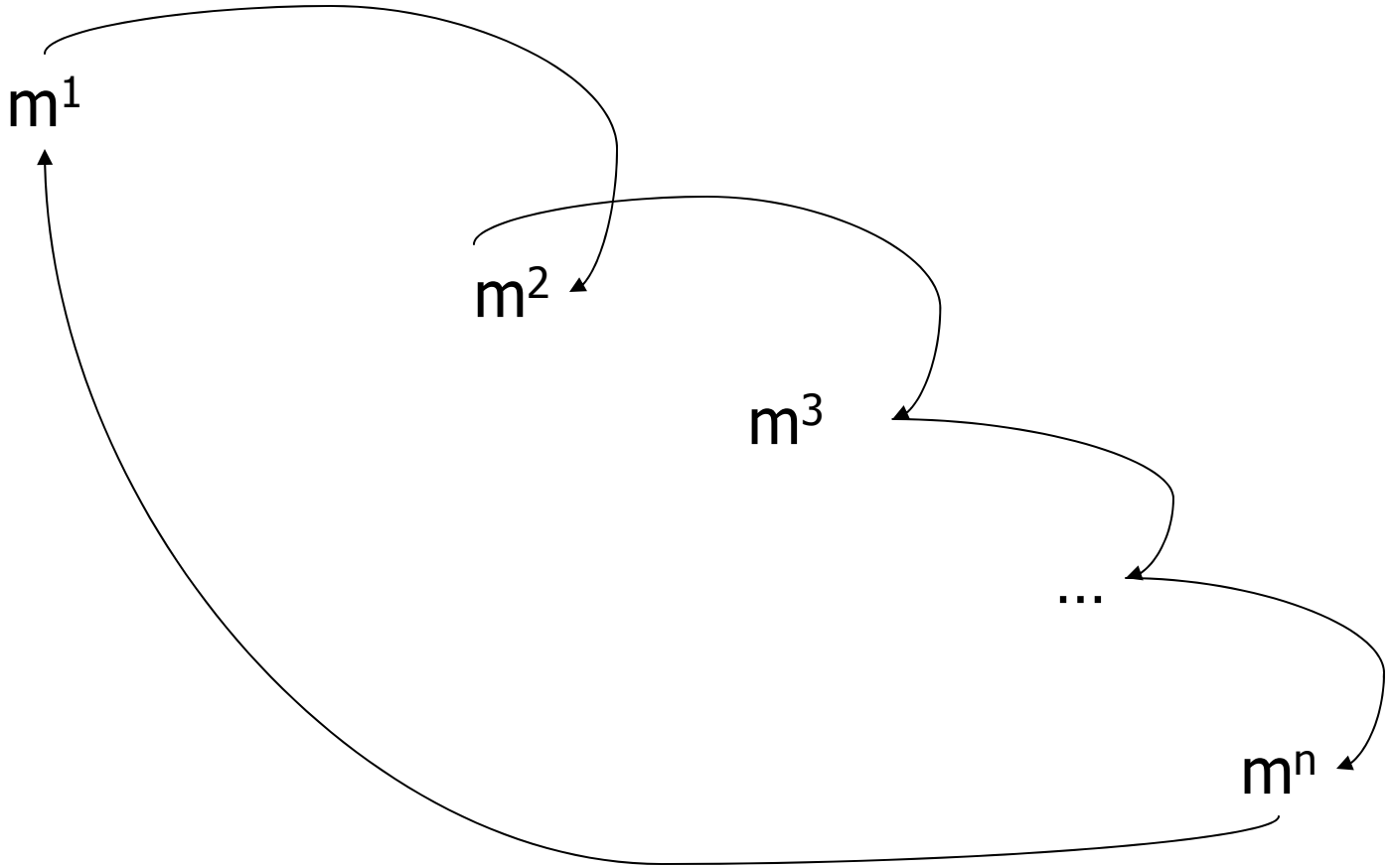



```
procedure proc;
begin
      :
   proc ();
      :
end;
```

Indirect Call



Indirect Call



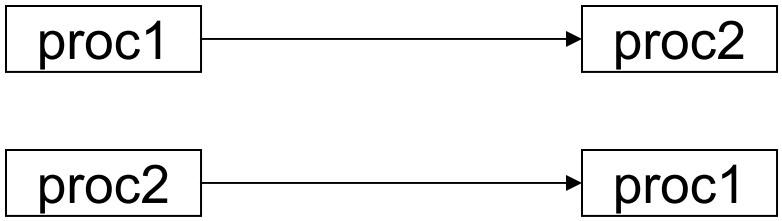
Indirect Call (2)

```
procedure proc1;
begin
      :
     proc2;
end;

procedure proc2;
begin
      :
    proc3;
end;

procedure proc3;
begin
      :
      proc1;
end;
```

An Issue With Indirect Recursion

For a full example look under
/home/231/examples/recursion/indirect.p

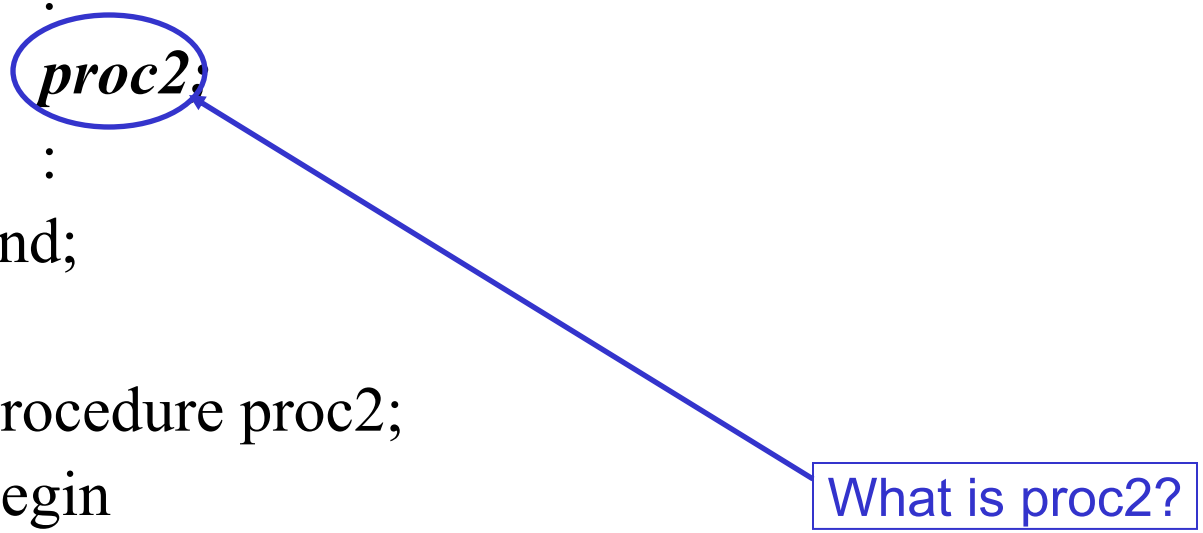
Example Scenario:



Which one should be defined first?

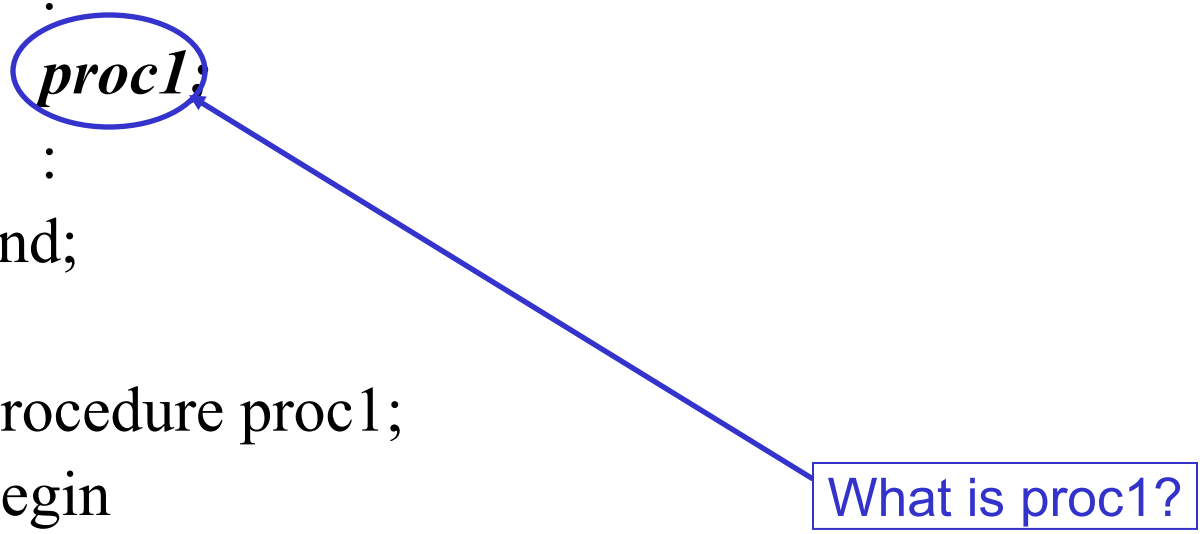
Procedure Proc1 First?

```
procedure proc1;
begin
    :
    proc2;
    :
end;

procedure proc2;
begin
    :
    proc1;
    :
end;
```



Procedure Proc2 First?

```
procedure proc2;
begin
    :
   proc1;
    :
end;

procedure proc1;
begin
    :
    proc2;
    :
end;
```



Solution: Use A Dummy Definition

A "placeholder" for the compiler (definition comes later)
Example problem

```
procedure proc1;
begin
    :
    proc2;
    :
end;

procedure proc2;
begin
    :
    proc1;
    :
end;
```

Solution: Use A Dummy Definition

A "placeholder" for the compiler (definition comes later)
Example problem

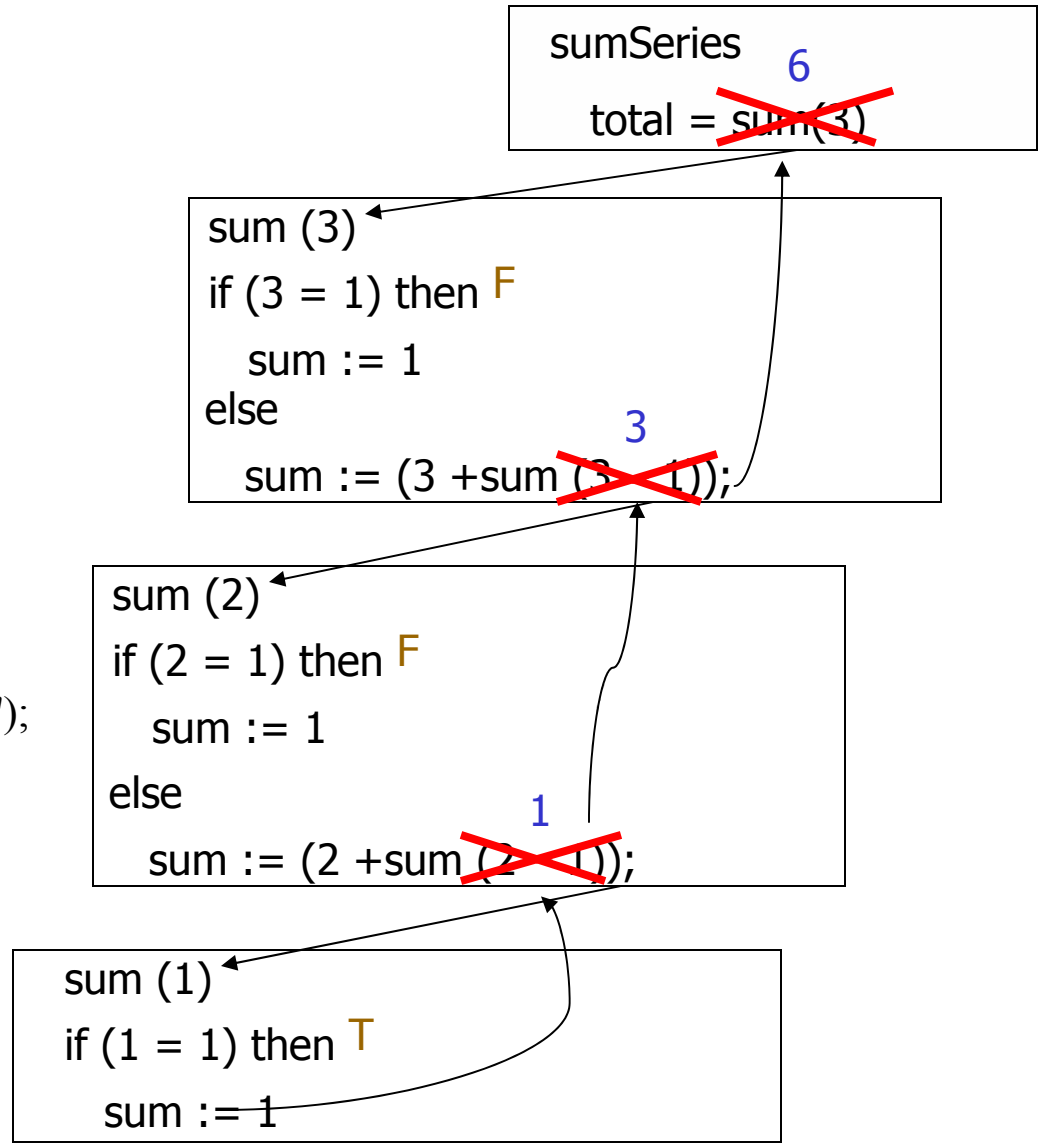
```
procedure proc2; FORWARD;
procedure proc1;
begin
    :
    proc2;
    :
end;

procedure proc2;
begin
    :
    proc1;
    :
end;
```

Requirements For Sensible Recursion

1) Base case
2) Progress is made (towards the base case)

Example Program

```
program sumSeries (input, output);

function sum (no : integer): integer;
begin
  if (no = 1) then
    sum := 1
  else
    sum:= (no + sum (no - 1));
end;

begin
  var lastNumber, total : integer;

  write('Enter the last number in the series :');
  readln(lastNumber);
  total := sum(lastNumber);
  writeln('Sum of the series from 1 to
    `lastNumber, ' is, ‘ total);
end.
```



When To Use Recursion

- When a problem can be divided into steps.
- The result of one step can be used in a previous step.
- There is scenario when you can stop sub-dividing the problem into steps and return to previous steps.
- All of the results together solve the problem.

When To Consider Alternatives To Recursion

- When a loop will solve the problem just as well
- Types of recursion:
  - Tail recursion
    —A recursive call is the last statement in the recursive module.
    —This form of recursion can easily be replaced with a loop.
  - Non-tail recursion
    —A statement which is not a recursive call to the module comprises the last statement in the recursive module.
    —This form of recursion is very difficult to replace with a loop.

Drawbacks Of Recursion

Function/procedure calls can be costly

- Uses up memory
- Uses up time

Benefits Of Using Recursion

- Simpler solution that's more elegant (for some problems)
- Easier to visualize solutions (for some people and certain classes of problems – typically require either: non-tail recursion to be implemented or some form of "backtracking")

Common Pitfalls When Using Recursion

- These three pitfalls can result in a segmentation fault occurring
  - No base case
  - No progress towards the base case
  - Using up too many resources (e.g., variable declarations) for each function call

No Base Case

```
function sum (no : integer): integer;
begin
    sum := (no + sum (no - 1));
end;
```

No Base Case

```
function sum (no : integer): integer;
begin
    sum := (no + sum (no - 1));
end;
```

When does it stop???

No Progress Towards The Base Case

```
function sum (no : integer): integer;
begin
   if (no = 1) then
      sum := 1
   else
      sum := (no + sum (no));
end;
```

Using Up Too Many Resources

For full example look under
/home/231/examples/recursion/resourceHog.p

```
procedure proc;
var
   arr : array [1..1000000] of char;
begin
     proc;
end;
```

Undergraduate Definition Of Recursion

Word: **re·cur·sion**

Pronunciation: ri-'k&r-zh&n

Definition: See recursion

Wav file from “The Simpsons”

You Should Now Know

- What is a recursive computer program
- How to write and trace simple recursive programs
- What are the requirements for recursion/What are the common pitfalls of recursion