COMP 202
Recursion

<u>CONTENTS</u>:
- Recursion
- Recursion vs Iteration
- Indirect recursion
- Runtime stacks

Recursive Thinking

- A *recursive definition* is one which uses the word or concept being defined in the definition itself
  - GNU
    - Gnu's Not Unix
  - LAME
    - Lame Ain't an MP3 Encoder

Recursive Definitions

- Consider the following list of numbers:

```
24, 88, 40, 37
```

- Such a list can be defined as

```
A LIST is a:  number
        or a:  number  comma  LIST
```

- That is, a LIST is defined to be a single number, or a number followed by a comma followed by a LIST
- The concept of a LIST is used to define itself

Recursive Definitions

- The recursive part of the LIST definition is used several times, terminating with the non-recursive part:

```
number comma LIST
  24     ,   88, 40, 37

             number comma LIST
               88     ,   40, 37

                          number comma LIST
                            40     ,   37

                                       number
                                         37
```

Infinite Recursion

- All recursive definitions have to have a non-recursive part
- If they didn't, there would be no way to terminate the recursive path
- Such a definition would cause *infinite recursion*
- This problem is similar to an infinite loop
- The non-recursive part is often called the *base case*

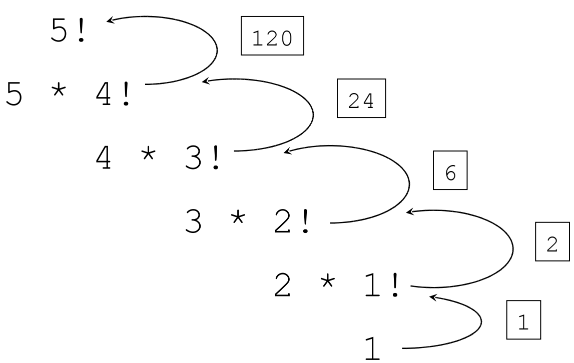
Recursive Definitions

- N!, for any positive integer N, is defined to be the product of all integers between 1 and N inclusive
- This definition can be expressed recursively as:

```
1!  =  1
N!  =  N * (N-1)!
```

- The concept of the factorial is defined in terms of another factorial
- Eventually, the base case of 1! is reached

Recursive Definitions



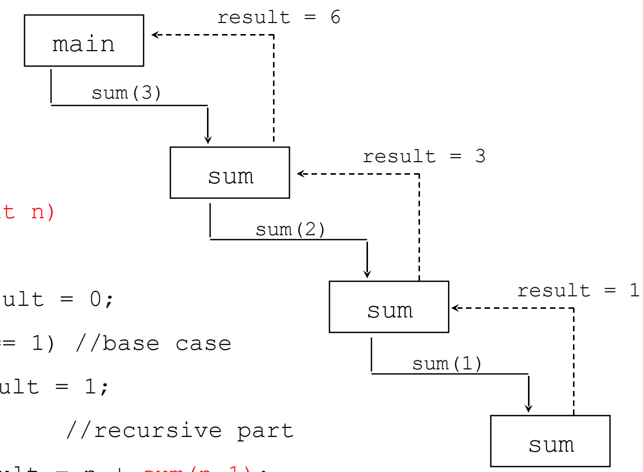
Recursive Programming

- A method in Java can invoke itself; if set up that way, it is called a *recursive method*
- The code of a recursive method must be structured to handle both the base case and the recursive case
- Each call to the method sets up a new execution environment, with new parameters and local variables
- As always, when the method completes, control returns to the method that invoked it (which may be an earlier invocation of itself)

Recursive Programming

- Consider the problem of computing the sum of all the numbers between 1 and any positive integer N
- Sum of 5 = 5 + 4 + 3 + 2 + 1

Recursive Programming




```
int sum(int n)
{
   int result = 0;
   if (n == 1) //base case
      result = 1;
   else        //recursive part
      result = n + sum(n-1);
   return result;
}
```


Recursive vs. Iterative

```
int sum_recursive(int n)
{
   int result = 0;
   if (n == 1) // base case
      result = 1;
   else if (n > 1) // recursive part
      result = n + sum_recursive(n-1);
   return result;
}
int sum_iterative(int n)
{
   int result = 0;
   for (int i = 1; i <=n; i++)
      result += i;
   return result;
}
```


Recursive Programming

- Note that just because we can use recursion to solve a problem, doesn't mean we should (there is a lot of overhead: method calls, variable declarations, etc.)
- For instance, we usually would not use recursion to solve the sum of 1 to N problem, because the iterative version is easier to understand
- However, for some problems, recursion provides an elegant solution, often cleaner than an iterative version
- You must carefully decide whether recursion is the correct technique for any problem

Palindrome Testing

```
public class PalindromeTesters {

   public static boolean iterativeTester (String str) {
      boolean result = false;
      int left = 0;
      int right = str.length() - 1;

      while (left < right && str.charAt(left) == str.charAt(right))  {
         left++;
         right--;
      }

      if (left >= right)  result = true;

      return result;
   }

   public static boolean recursiveTester (String str)   {

      boolean result = false;

      if (str.length() <= 1)  result = true;
      else  result = (str.charAt(0) == str.charAt(str.length() - 1)) &&
                     recursiveTester(str.substring(1,str.length()-1));

      return result;

   }
}
```


When to use recursion…

- Notice that we have many ways to iterate:
  - Do…while
  - While
  - For
  - Recursion
- They all do the same thing, so selecting between then should be based on some benefit:
  - Easier to program using that loop
  - Runs faster with that particular loop
- Ideally you want to optimize on both criteria

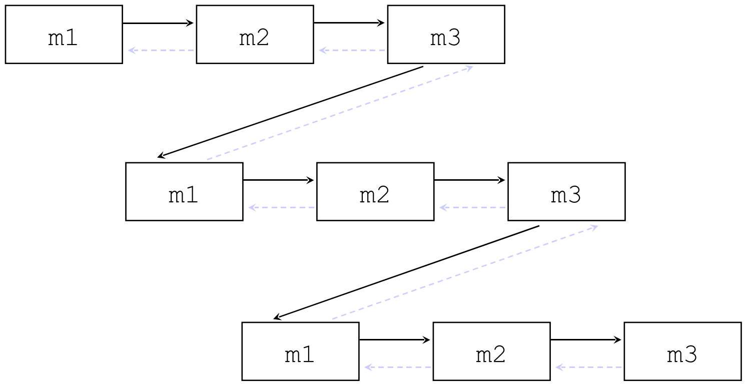
Designing For Recursion

- Solution requires iteration
- Algorithm always looks like this:
  - Base Case
    - The part of the loop that has the stop condition. It also returns the default (simplest case) result
  - Incrementing Part
    - The part of the program that moves us on to the next data value.
      - Incrementing variable
      - Reading data
      - Moving to a new data item in a structure (like array)
  - Recursion Part
    - The part of the program that initiates the iteration
- Note that the Incrementing and Recursion Parts are often together in the same statement (but not always so)

Indirect Recursion

- A method invoking itself is considered to be *direct recursion*
- A method could invoke another method, which invokes another, etc., until eventually the original method is invoked again
- For example, method `m1` could invoke `m2`, which invokes `m3`, which in turn invokes `m1` again
- This is called *indirect recursion*, and requires all the same care as direct recursion
- It is often more difficult to trace and debug

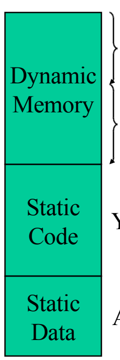
Indirect Recursion



Part 2

The Run-Time Stack

An Executing Program in RAM



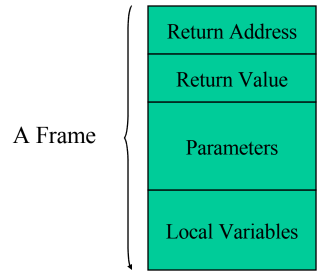
Run-time Heap: used for dynamic data (more next week)

Run-time Stack: stores local variables and function call management

Your compiled code

All non-local data and all literals

Function Call “Frame”



- At every call to a function a frame is added to the TOP of the stack. This is referred to as a PUSH.
- When the function terminates the frame is removed from the top of the stack. This is referred to as a POP.
- Stacks function much like a stack of plates. You put them on the top and you remove them from the top.

Problem

Write the factorial program recursively and then construct the run-time stack. Write a main method that invokes the method factorial. Now draw the run-time stack from the moment the main method is invoked to the moment the main method terminates. Show how it updates and how it produces the correct results.