Chapter 11: Recursion

- Recursion is a fundamental programming technique that can provide an elegant solution certain kinds of problems
- Chapter 11 focuses on:
  - thinking in a recursive manner
  - programming in a recursive manner
  - the correct use of recursion
  - recursion examples

Recursive Thinking

- A *recursive definition* is one which uses the word or concept being defined in the definition itself
- When defining an English word, a recursive definition is often not helpful
- But in other situations, a recursive definition can be an appropriate way to express a concept
- Before applying recursion to programming, it is best to practice thinking recursively

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, but the non-terminating "loop" is part of the definition itself
- The non-recursive part is often called the *base case*

Recursive Definitions

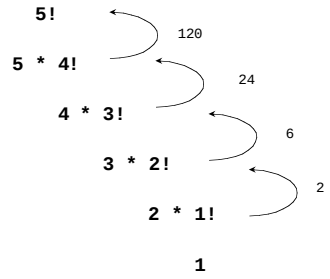
- N!, for any positive integer N, is defined to be the product of all integers between 1 and N inclusive
- This definition can be expressed recursively as:

```
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

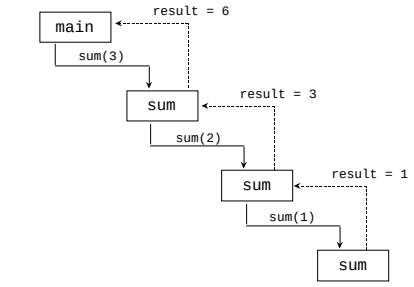
- Consider the problem of computing the sum of all the numbers between 1 and any positive integer N
- This problem can be recursively defined as:

$$\sum_{i=1}^{N} = N + \sum_{i=1}^{N-1} = N + (N-1) + \sum_{i=1}^{N-2}$$

$$= \text{ etc.}$$

- See `Recursive_Sum.java`

Recursive Programming



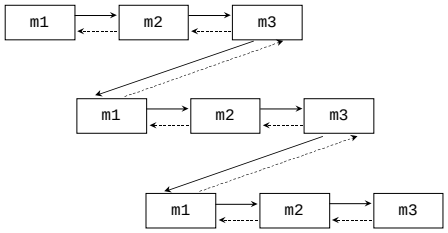
Recursive Programming

- Note that just because we can use recursion to solve a problem, doesn't mean we should
- 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

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



Using Recursion

- A maze is solved by trial and error -- choosing a direction, following a path, returning to a previous point if the wrong move is made
- As such, it is another good candidate for a recursive solution
- The base case is an invalid move or one which reaches the final destination
- See `MazeSearch.java`
- See `SolveTowers.java`

Using Recursion

- Recursion is best served when it is easy to define a smaller subset of the problem in terms of the original
- Consider the task of repeatedly displaying a set of images in a mosaic that is reminiscent of looking in two mirrors reflecting each other
- The base case is reached when the area for the images shrinks to a certain size
- See `MirroredPictures.java`