Nested subroutine call

\[ f(x, y) = \sqrt{x \cdot y} \]
Handling recursive procedure calls

Example. Compute factorial (n)

```c
int fact (int n)
{
    if (n < 1) return (1);
    else return (n * fact(n-1))
}
```

(Plan) Put n in $a0. Result should be available in $v0.

{Structure of the fact procedure}

```
fact:    subi $sp, $sp, 8
        sw $ra, 4($sp) {why?}
        sw $a0, 0($sp)
```

OLD

NEW

$sp (current top of the stack)
The growth of the stack as the recursion unfolds
Now test if \( n < 1 \) (i.e. \( n = 0 \)). In that case return 1 to \( v0 \)

```
slti  $t0, $a0, 1         # if \( n \geq 1 \) then goto L1
beq  $t0, $zero, L1
addi $v0, $zero, 1       # return 1 to \( v0 \)
addi $sp, $sp, 8         # pop 2 items from stack
jr   $ra                  # return
L1:  addi $a0, $a0, -1    # decrement \( n \)
      jal  fact            # call fact with (\( n - 1 \))
```

Now, we need to compute \( n \ast \text{fact}\,(n-1) \)

```
lw   $a0, 0($sp)          # restore argument \( n \)
lw   $ra, 4($sp)          # restore return address
addi $sp, $sp, 8         # pop 2 items
mult $v0, $a0, $v0       # return \( n \ast \text{fact}\,(n-1) \)
jr   $ra                  # return to caller
```
Run time environment of a MIPS program

Stack pointer

Temporary local variables

Return address

Saved argument registers beyond a0-a3

Frame

Low address

Growth of stack

High address
A translation hierarchy

HLL program

COMPILER

Assembly language program

ASSEMBLER

Machine language module

LINKER ← Library routine

Executable machine language program

LOADER

Memory
What are Assembler directives?

Instructions that are not executed, but they tell the assembler about how to interpret something. Here are some examples:

```
.text
{Program instructions here}

.data
{Data begins here}
.byte 84, 104, 101
.asciiz "The quick brown fox"
.float f1, . . . , fn
.word w1, . . . , wn
.space n {reserve n bytes of space}
```
How does an assembler work?

In a two-pass assembler

PASS 1: Symbol table generation
PASS 2: Code generation

Follow the example in the class.