MIPS Instruction formats

R-type format

opcode	rs	rt	rd	shift amt	function
6	5	5	5	5	6
	↑	↑	↑		
	src	src	dst		

Used by **add, sub** etc.

I-type format

opcode	rs	rt	address
6	5	5	16
	↑	↑	↑
	base	dst	offset

Used by lw (load word), sw (store word) etc

There is one more format: the J-type format. Each MIPS instruction must belong to one of these formats.

The instruction format for jump

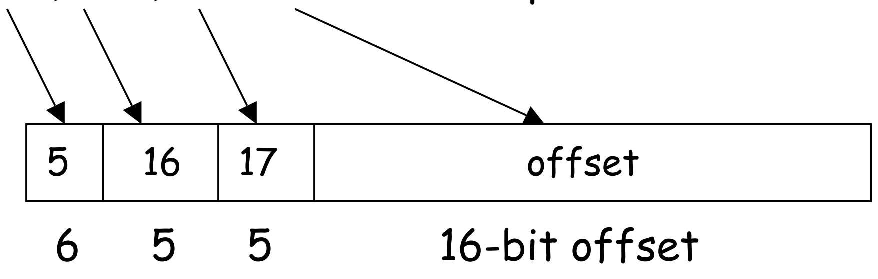
J 10000 is represented as

2	10000
6-bits	26 bits

This is the J-type format of MIPS instructions.

Conditional branch is represented using I-type format:

bne $s0, $s1, 1234 is represented as



PC + offset determines the branch target.

This is called **PC-relative addressing**.

Revisiting machine language of MIPS

(check out pp 101-105)

```
Loop:   add  $t1, $s3, $s3     # starts from 80000
        add  $t1, $t1, $t1
        add  $t1, $t1, $s6
        lw   $t0, 0($t1)
        bne  $t0, $s5, Exit
        add  $s3, $s3, $s4
        j    Loop
Exit:
```

	6	5	5	5	5	6	
80000	0	19	19	9	0	32	R-type
80004	0	9	9	9	0	32	R-type
80008	0	9	22	9	0	32	R-type
80012	35	9	8		0		I-type
80016	5	8	21		2		I-type
80020	0	19	20	19	0	32	R-type
80024	2	20000					J-type
80028							

MIPS Addressing Modes

What are the different ways to access an operand?

- **Register addressing**

  Operand is in register

  add $s1, $s2, $s3 means $s1 ← $s2 + $s3

- **Base addressing**

  Operand is in memory.

  The address is the sum of a register and a constant.

  lw $s1, 32($s3) means $s1 ← M[s3 + 32]

  As special cases, you can implement

  Direct addressing $s1 ← M[32]

  Indirect addressing $s1 ← M[s3]

  Which helps implement pointers.

- **Immediate addressing**

  The operand is a constant.

  How can you execute $s1 □ 7?

  addi $s1, $zero, 7 means $s1 □ 0 + 7

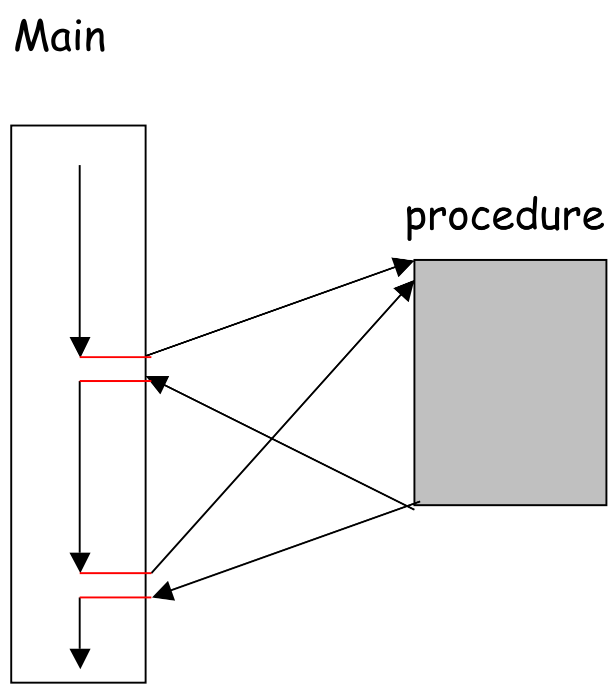
  (add immediate, uses the I-type format)

- **PC-relative addressing**

  The operand address = PC + an offset

  Implements position-independent codes. A small offset is adequate for short loops.

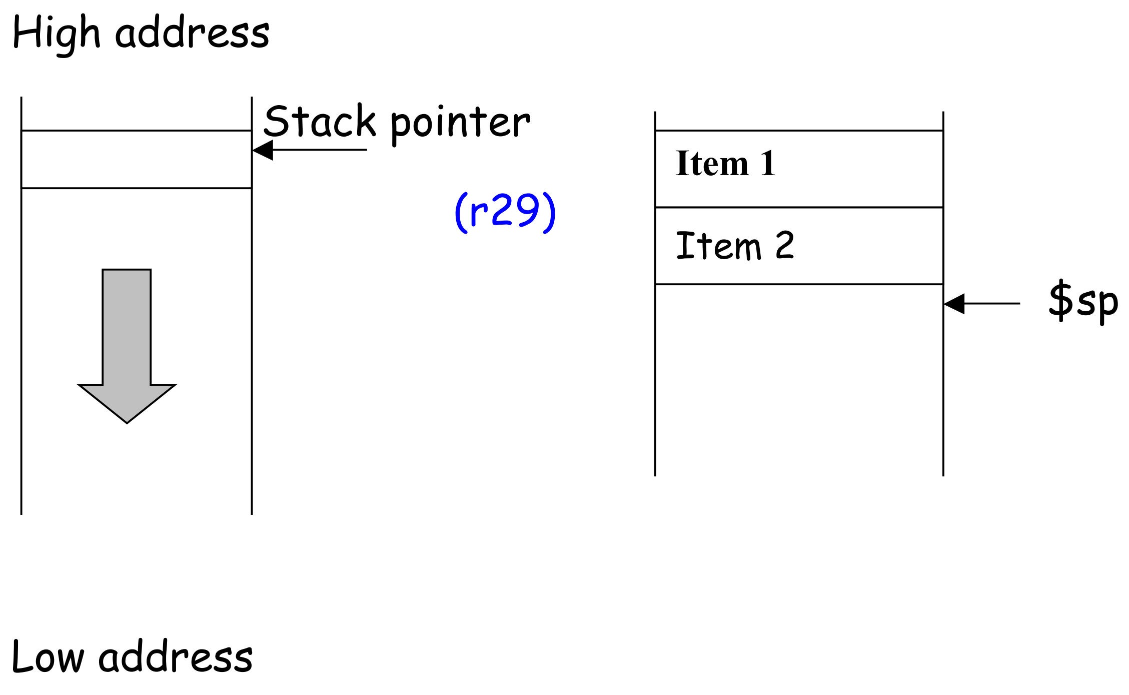
Procedure Call



Uses a stack. What is a stack?

The stack

Occupies a part of the main memory. In MIPS, it grows from high address to low address as you push data on the stack. Consequently, the content of the stack pointer ($sp) decreases.



Use of the stack in procedure call

Before the subroutine executes, save registers.

Jump to the subroutine using jump-and-link (jal address)

(jal address means ra ← PC + 4; PC ← address)

After the subroutine executes, restore the registers.

Return from the subroutine using jr (jump register)

(jr ra means PC ← (ra))

Example

```
int leaf (int g, int h, int i, int j)
{
        int f;
        f = (g + h) – (i + j);
        return f;
}
```

The arguments g, h, i, j are put in $a0-$a3.

The result f is put into $s0, and returned to $v0.

The structure of the procedure

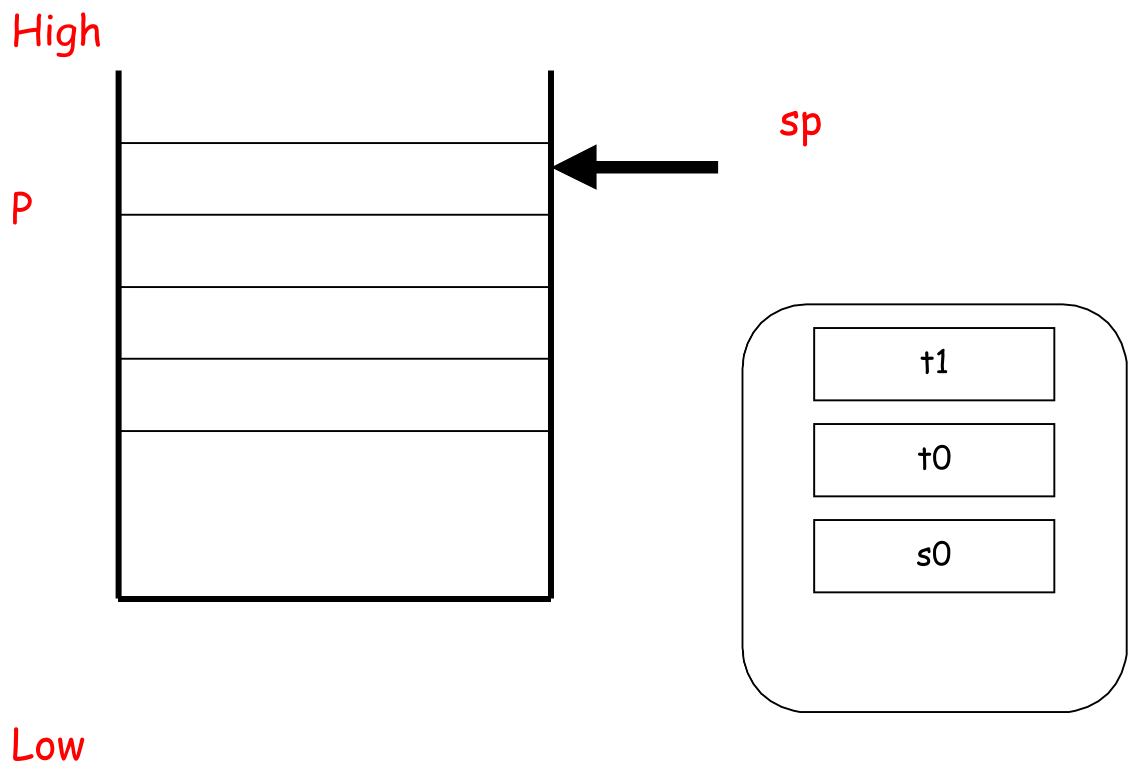
```
Leaf:   subi $sp, $sp, 12    # $sp = $sp-12, make room
        sw $t1, 8($sp)       # save $t1 on stack
        sw $t0, 4($sp)       # save $t0 on stack
        sw $s0, 0($sp)       # save $s0 on stack
```

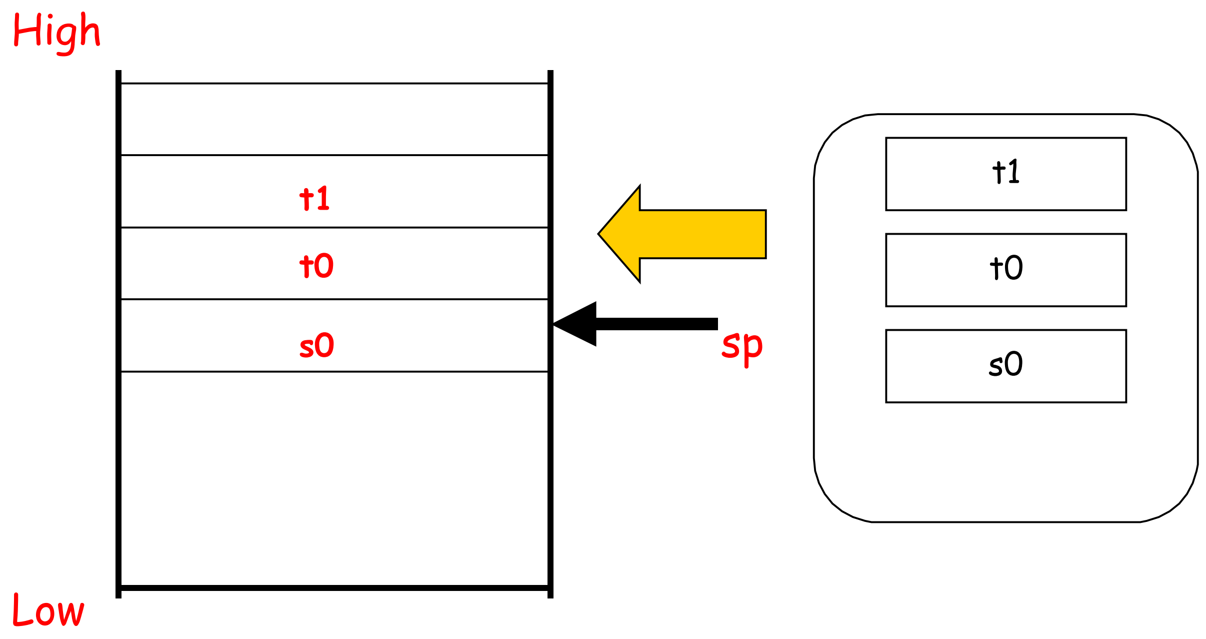
Now we can use the registers $t1, $t0, $s0 in the body of the procedure.

```
        add $t0, $a1, $a2        # $t0 = g + h
        add $ t1, $a2, $a3       # $t1 = i + j
        sub $s0, $t0, $t1        # $s0 = (g + h) – (i + j)
```

Return the result into the register $v0.

```
add $v0, $s0, $zero     # returns f = (g+h)-(i+j) to $v0
```


High
sp
P
t1
t0
s0
Low


High
t1
t0
s0
sp
t1
t0
s0
Low

Now restore the old values of the registers by popping the stack.

```
lw $s0, 0($sp)        # restore $s0
lw $t0, 4($sp)        # restore $t0
lw $t1, 8($sp)        # restore $t1
addi $sp, $sp, 12     # adjust $sp
```

Finally, return to the main program.

```
jr $ra                # return to caller.
```

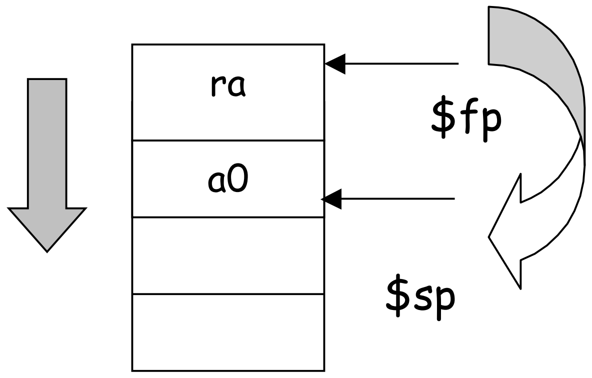
A recursive procedure

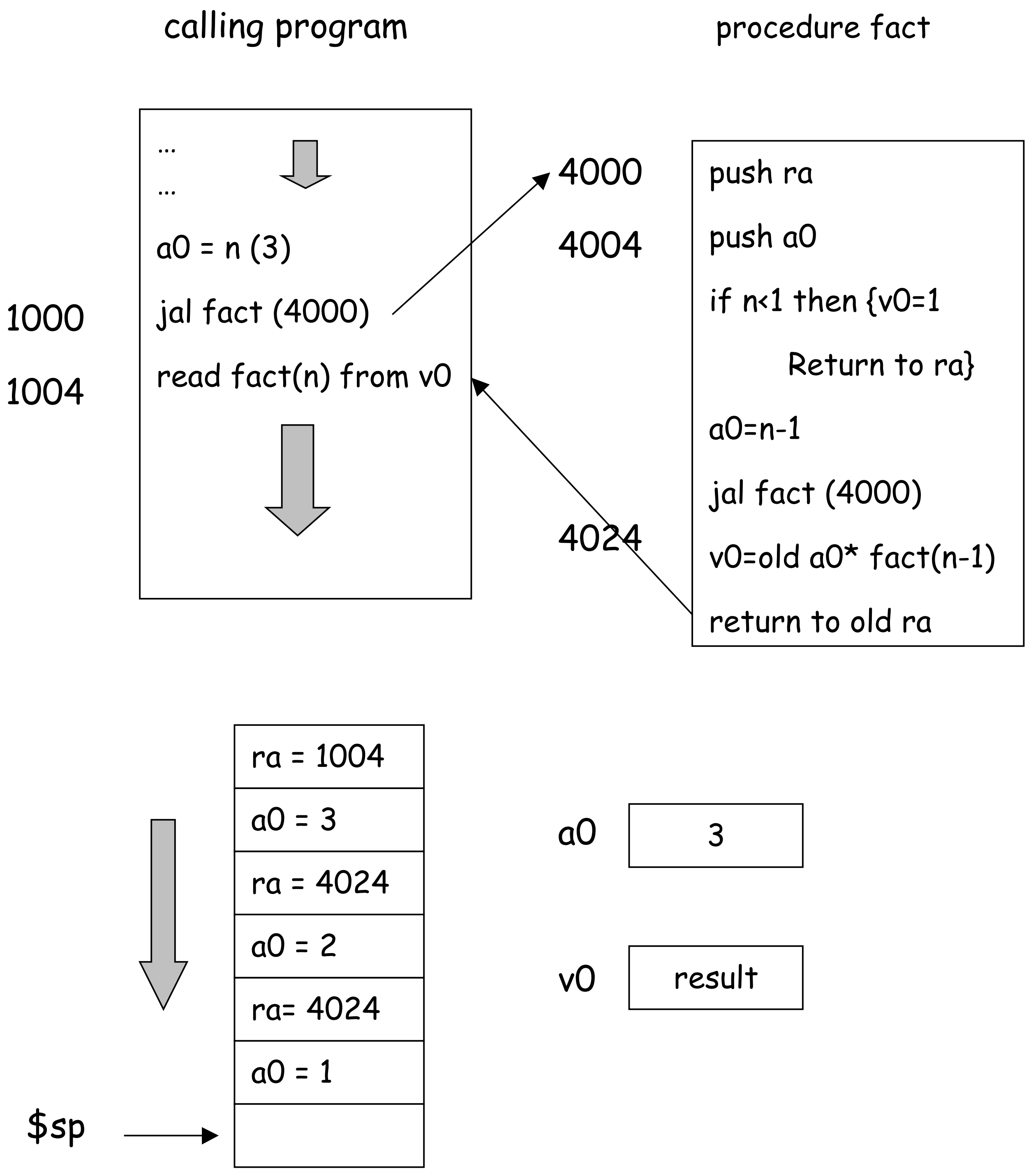
Example. Compute factorial (n)

```
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.

```
fact:       sub   $sp, $sp, 8
            sw    $ra, 4($sp)
            sw    $a0, 0($sp)
```





```
...
...
a0 = n (3)
jal fact (4000)
read fact(n) from v0
```

```
push ra
push a0
if n<1 then {v0=1
        Return to ra}
a0=n-1
jal fact (4000)
v0=old a0* fact(n-1)
return to old ra
```

Now test if n < 1 (i.e. n = 0). In that case return 0 to $v0

```
     slti  $t0, $a0, 1        # if n ≥ 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:  subi  $a0, $a0, 1        # decrement n
     jal   fact               # call fact with (n – 1)
```

Now, we need to compute n * 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 * fact(n-1)
     jr    $ra                # return to caller
```