# Code Generation, Continued

# How to be a MIPS Master

It’s really easy to get confused with assembly

- Try writing a program by hand before having the compiler generate it
- Draw lots of pictures of program flow
- Have your compiler output detailed comments

Get help

- Post on piazza

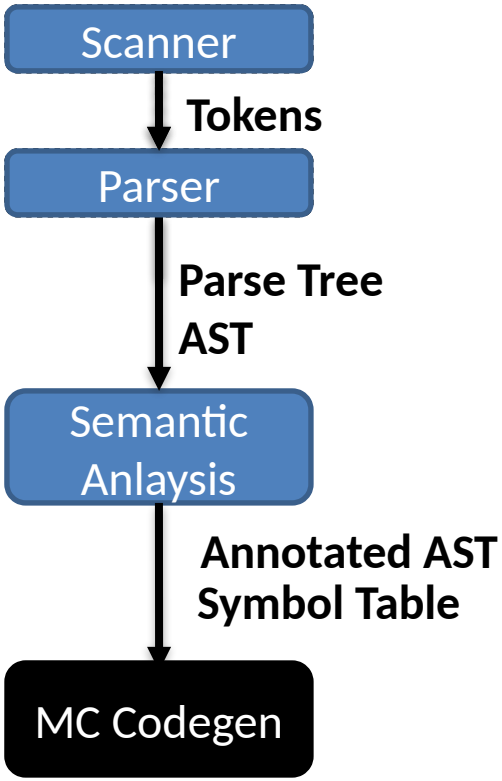
# Roadmap

Last time:

- Talked about compiler backend design points
- Decided to go with direct to machine code design for our language

This time:

- Run through what the actual codegen pass will look like



# Review: Global Variables

Showed you one way to do declaration last time:

```
.data
.align 2
_name: .space 4
```

Simpler form for primitives:

```
.data
_name: .word <value>
```

# Review: Functions

Preamble

– Sort of like the function signature

Prologue

– Set up the function

Body

– Do the thing

Epilogue

– Tear down the function

# Function Preambles

```
int f(int a, int b){
    int c = a + b;
    int d = c – 7;
    return c;
}
```

```
.text
f:
#... Function body ...
```

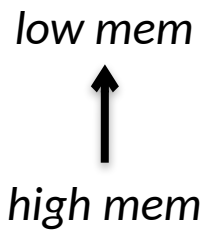
**This label gives us something to jump to**

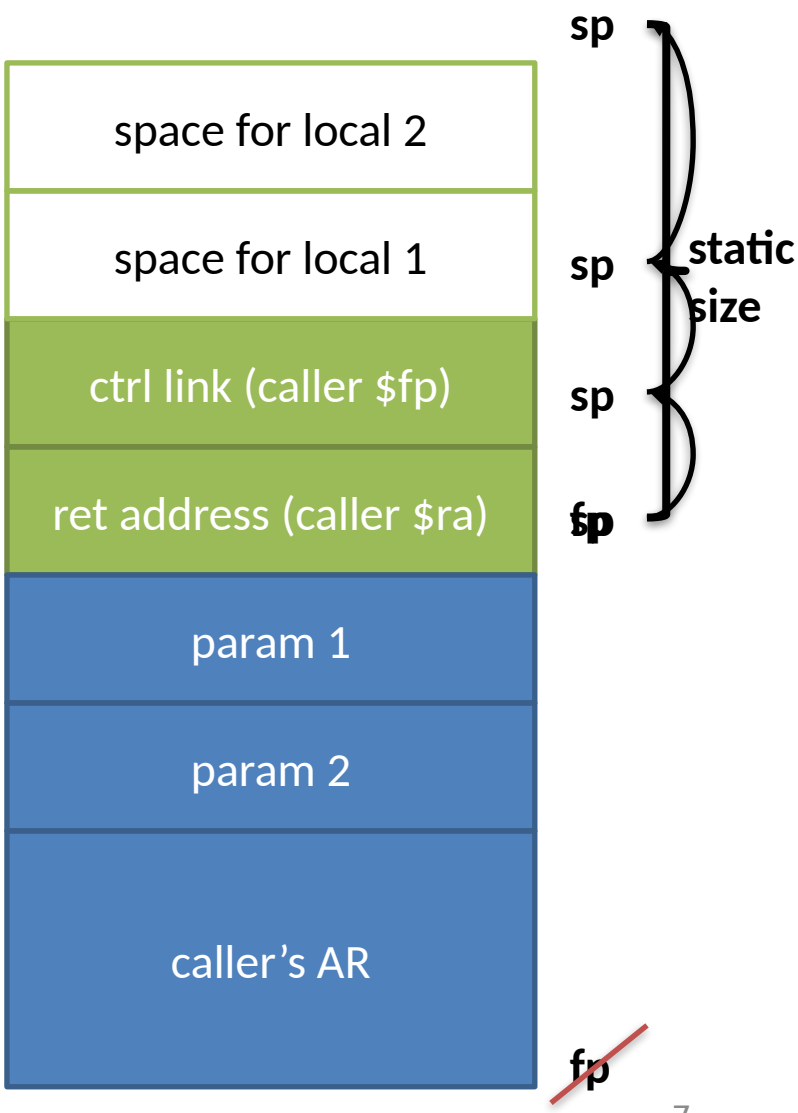
```
jal f
```

# Function Prologue

Recall our view of the Activation Record

1. save the return address
2. ~~save the frame pointer~~
3. make space for locals
4. update the frame ptr



# Function Prologue: MIPS

Recall our view of the Activation Record

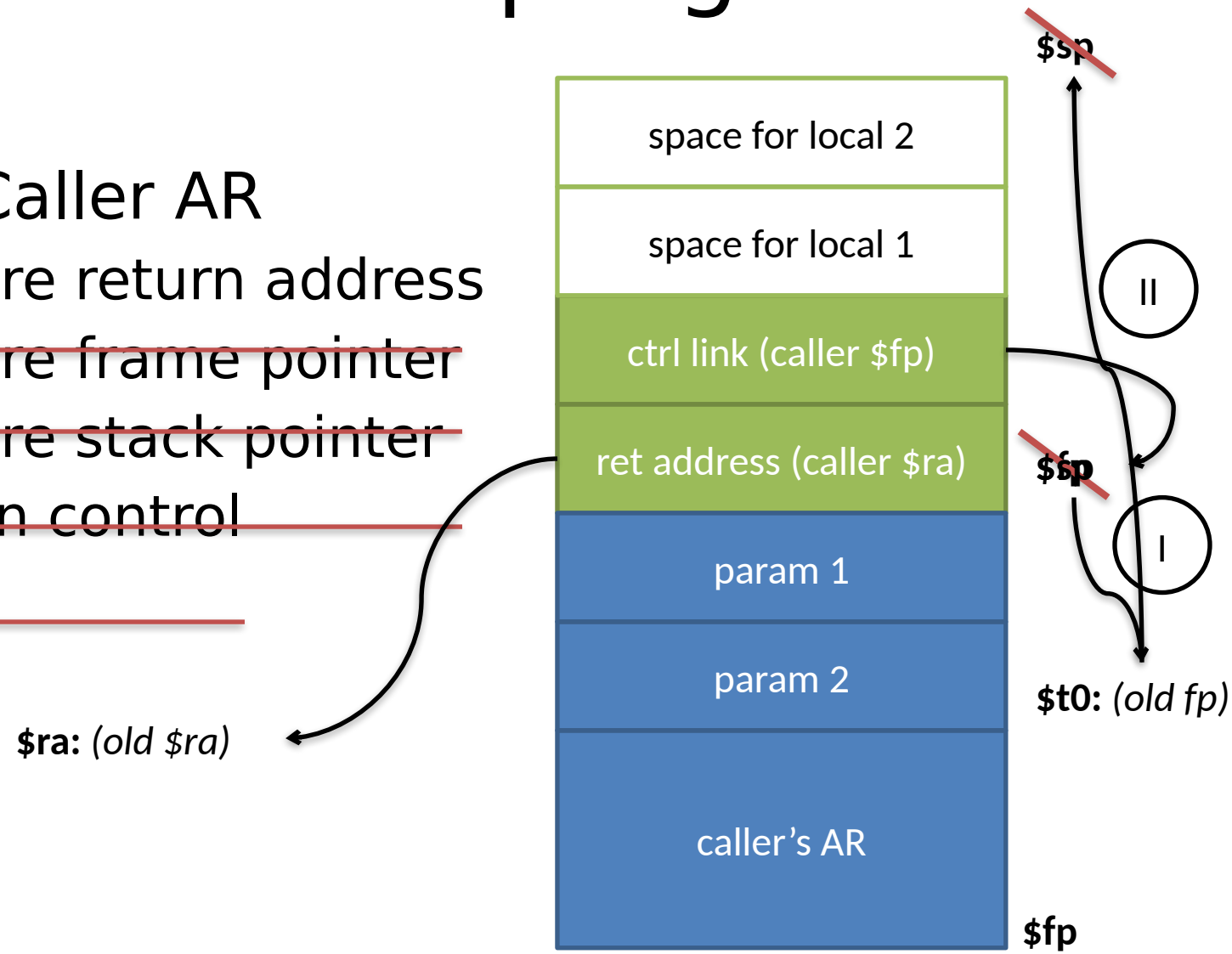
1. save the return address
2. ~~save the frame pointer~~
3. make space for locals
4. update the frame ptr

```
.text
f:
  sw $ra 0($sp)   #call lnk
  subu $sp $sp 4  # (push)
  sw $fp 0($sp)   #ctrl lnk
  subu $sp $sp 4  # (push)
  subu $sp $sp 8  #locals
  addu $fp $sp 16 #update fp
```

# Function Epilogue

Restore Caller AR

1. restore return address
2. ~~restore frame pointer~~
3. ~~restore stack pointer~~
4. ~~return control~~



# Function Epilogue: MIPS

Restore Caller AR

1. restore return address
2. ~~restore frame pointer~~
3. ~~restore stack pointer~~
4. ~~return control~~

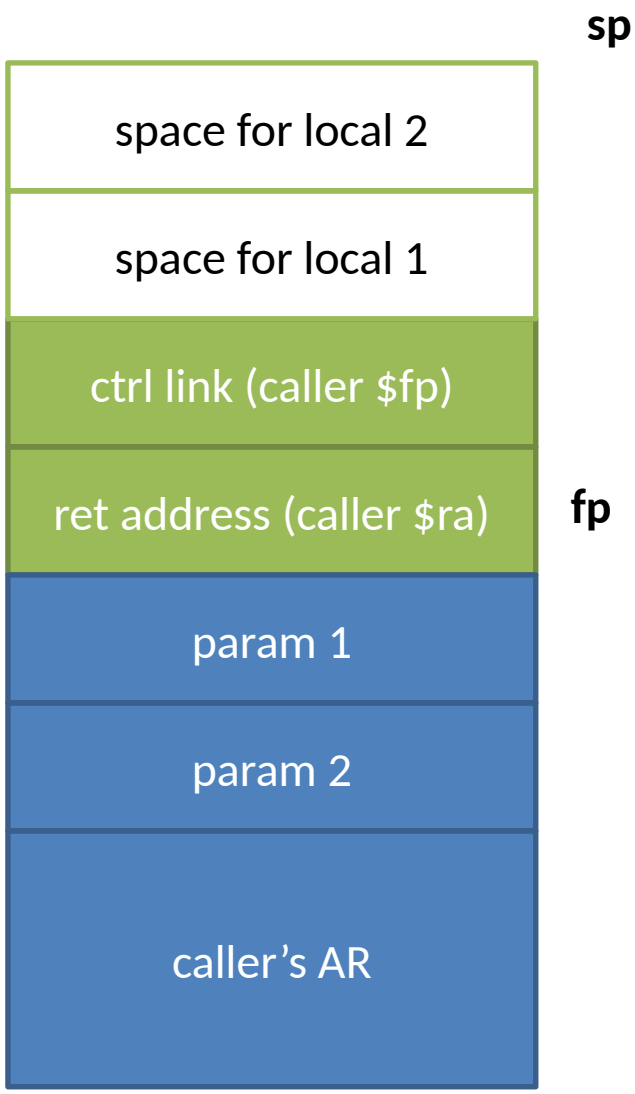
```
.text
f:
  sw $ra 0($sp)
  subu $sp $sp 4
  sw $fp 0($sp)
  subu $sp $sp 4
  subu $sp $sp 8
  addu $fp $sp 16
  #... Function body ...
  lw $ra, 0($fp)
  move $t0, $fp
  lw $fp, -4($fp)
  move $sp, $t0
  jr $ra
```

# Function Body

Obviously, quite different based on content

- Higher-level data constructs
  - Loading parameters, setting return
  - Evaluating expressions
- Higher-level control constructs
  - Performing a call
  - Loops
  - Ifs

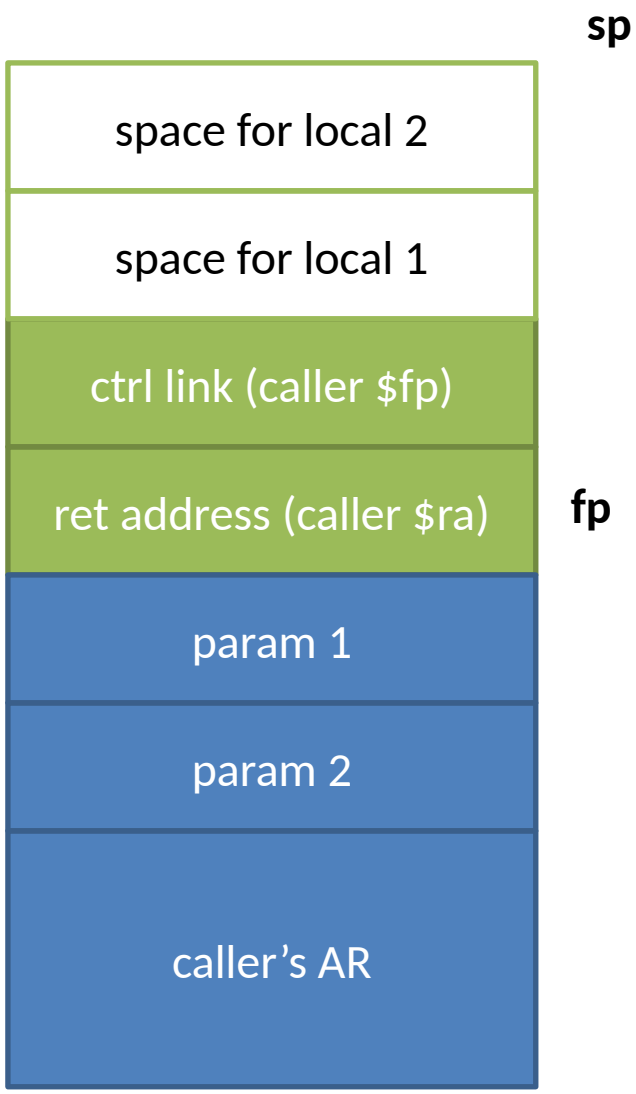
# Function Locals




```
.text
f:
    # … prologue … #
    lw $t0, -8($fp)
    lw $t1, -12($fp)


    # … epilogue … #
```

# Function Returns




```
.text
f:
    # … prologue … #
    lw $t0, -8($fp)
    lw $t1, -12($fp)
    lw $v0, -8($fp)
    j f_exit
f_exit:
    # … epilogue … #
```

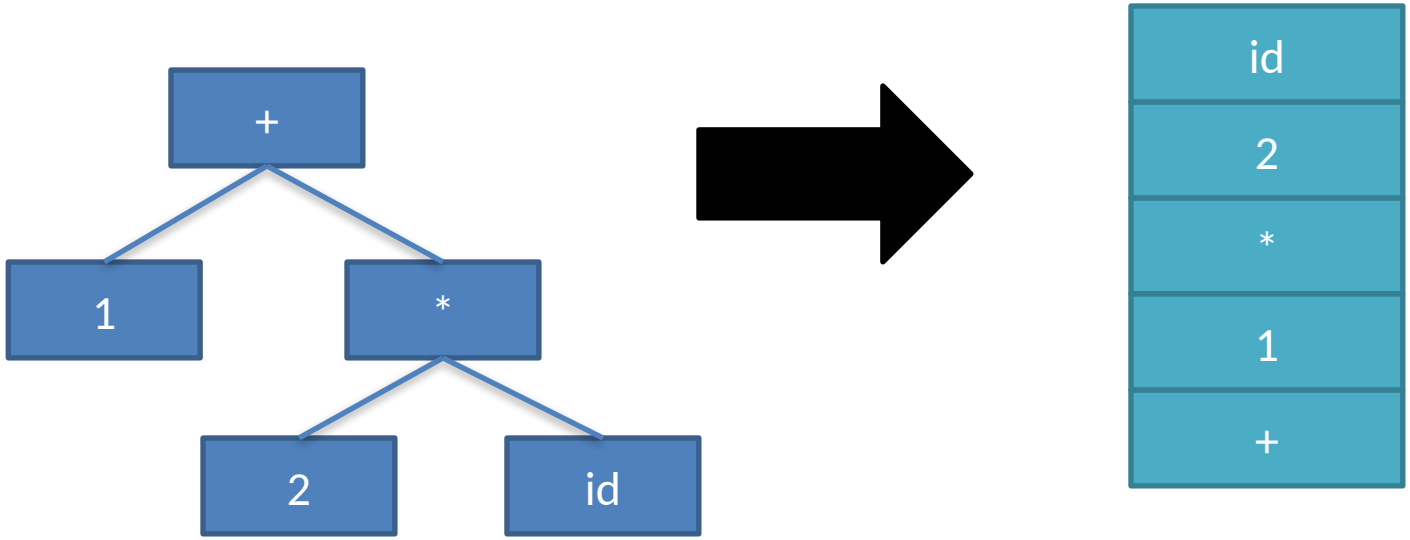
# Function Body: Expressions

Goal

- Serialize ("flatten") an expression tree

Use the same insight as the parser

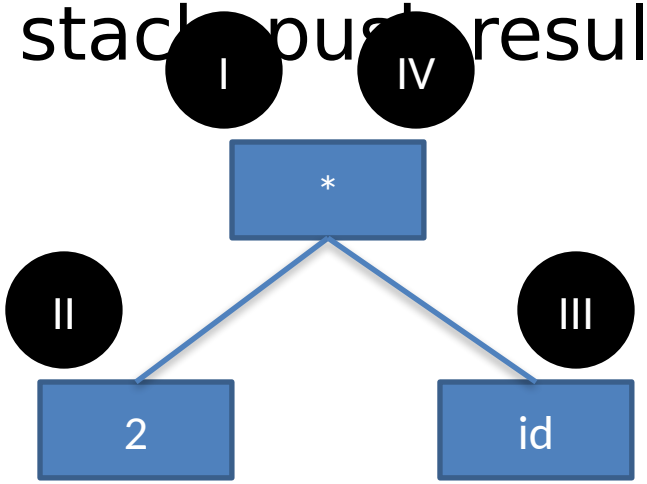
- Use a work stack and a post-order traversal



# Serialized Psuedocode

Key insight

- Use the stack pointer location as “scratch space”
- At operands: push value onto the stack
- At operators: pop source values from stack, push result




```
push 2
push id
pop id into t1
pop 2 into t0
mult t0 * t1 into t0
push t0
```

$t1 = id

$t0 = ~~2~~ 2 * id

# Serialized MIPS

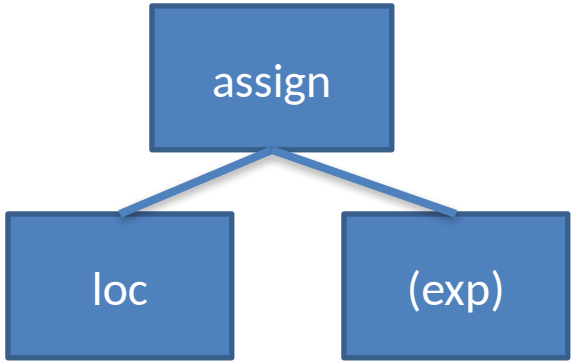
L1: push 2
L2: push id
L3: pop id into t1
L4: pop 2 into t0
L5: mult t0 * t1 into t0
L6: push t0

```
L1: li $t0 2
    sw $t0 0($sp)
    subu $sp $sp 4
L2: lw $t0 id
    sw $t0 0($sp)
    subu $sp $sp 4
L3: lw $t1 4($sp)
    addu $sp $sp 4
L4: lw $t0 4($sp)
    addu $sp $sp 4
L5: mult $t0 $t0 $t1
L6: sw $t0 0($sp)
    subu $sp $sp 4
```

# Stmts

By the end of the expression, our stack isn't exactly as we left it

- Contains the result of the expression
- This is by design

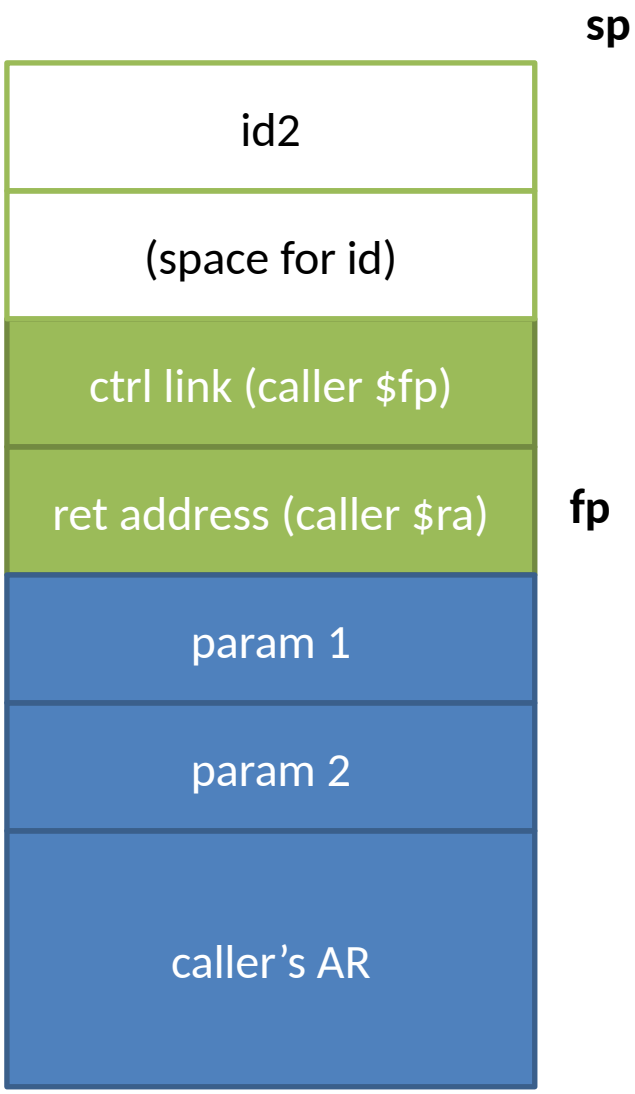



1) Compute RHS expr on stack
2) Compute LHS *location* on stack
3) Pop LHS into $t1
4) Pop RHS into $t0
5) Store value $t0 at address $t1

# Simple Assign, You Try

Generate stack-machine style MIPS code for

id = 1 + 2;




**<u>Algorithm</u>**

1) Compute RHS expr on stack
2) Compute LHS *location* on stack
3) Pop LHS into $t1
4) Pop RHS into $t0
5) Store value $t0 at address $t1

# Dot Access

Fortunately, we know the offset from the base of a struct to a certain field statically

- The compiler can do the math for the slot address
- This isn't true for languages with pointers!

```
struct Demo inst;
struct Demo inst2;
inst.b.c = inst2.b.c + 1;
```

load this address  load this value

# Dot Access Example

```
void v(){
    struct Inner{
      bool hi;
      int there;
      int c;
    };
    struct Demo{
      struct Inner b;
      int val;
    };
    struct Demo inst;
    inst.b.c = inst.b.c;
}
```

**inst is based at -8($fp )**

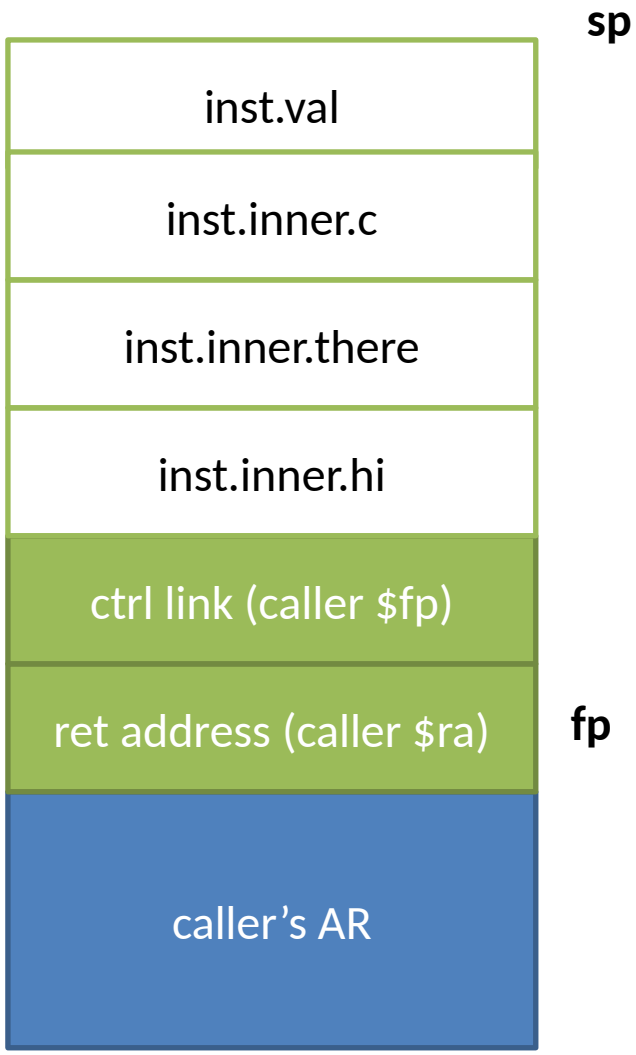
**field b.c is -8 off the base**

**LHS**

```
subu $t0 $fp 16
sw $t0 0($sp)
```

**RHS**

```
lw $t0 -16($fp)
sw $t0 0($sp)
subu $sp $sp 4
```



# Control Flow Constructs

Function Calls

Loops

Ifs

We do these next time

# Function Call Example

```
int f(int arg1, int arg2){
  return 2;
}
int main(){
  int a;
  a = f(a,4);
}
```

```
li $t0 4          # push arg 2
sw $t0 0($sp)     #
subu $sp $sp 4    #
lw $t0 -8($fp)    # push arg 1
sw $t0 0($sp)     #
subu $sp $sp 4    #
jal f             # goto f
addu $sp $sp 8    # tear down params
sw $v0 -8($fp)    # retrieve result
```

# Summary

Today:

- Got the basics of MIPS
- CodeGen for *some* AST node types

Next time:

- Do the rest of the AST nodes
- Introduce control flow graphs