ECE 220 Computer Systems & Programming

Lecture 10 – Implementing Function in C and Run-Time Stack

February 14, 2019

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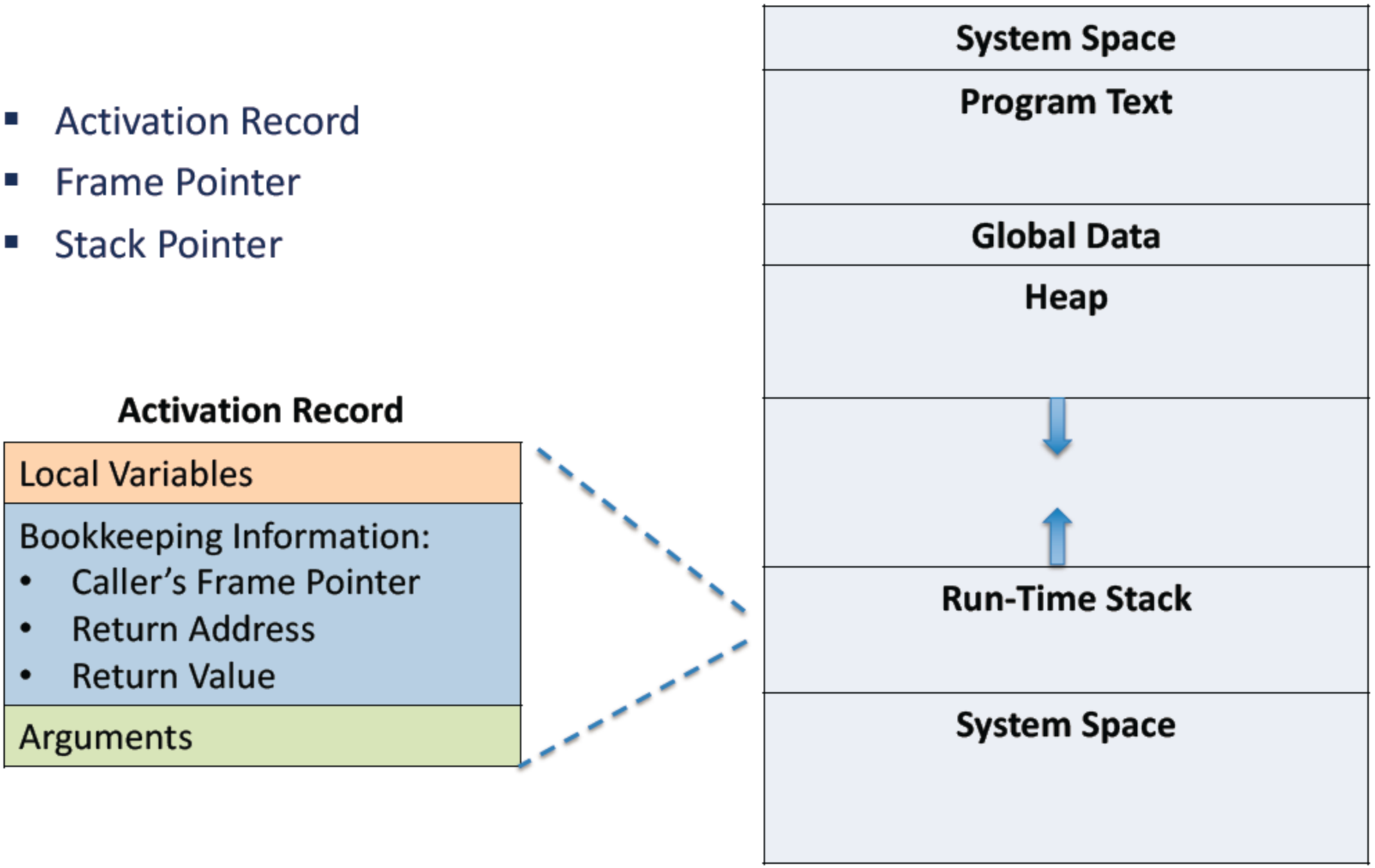
Lecture 9 Review

- Activation Record
- Frame Pointer
- Stack Pointer



Run-Time Stack

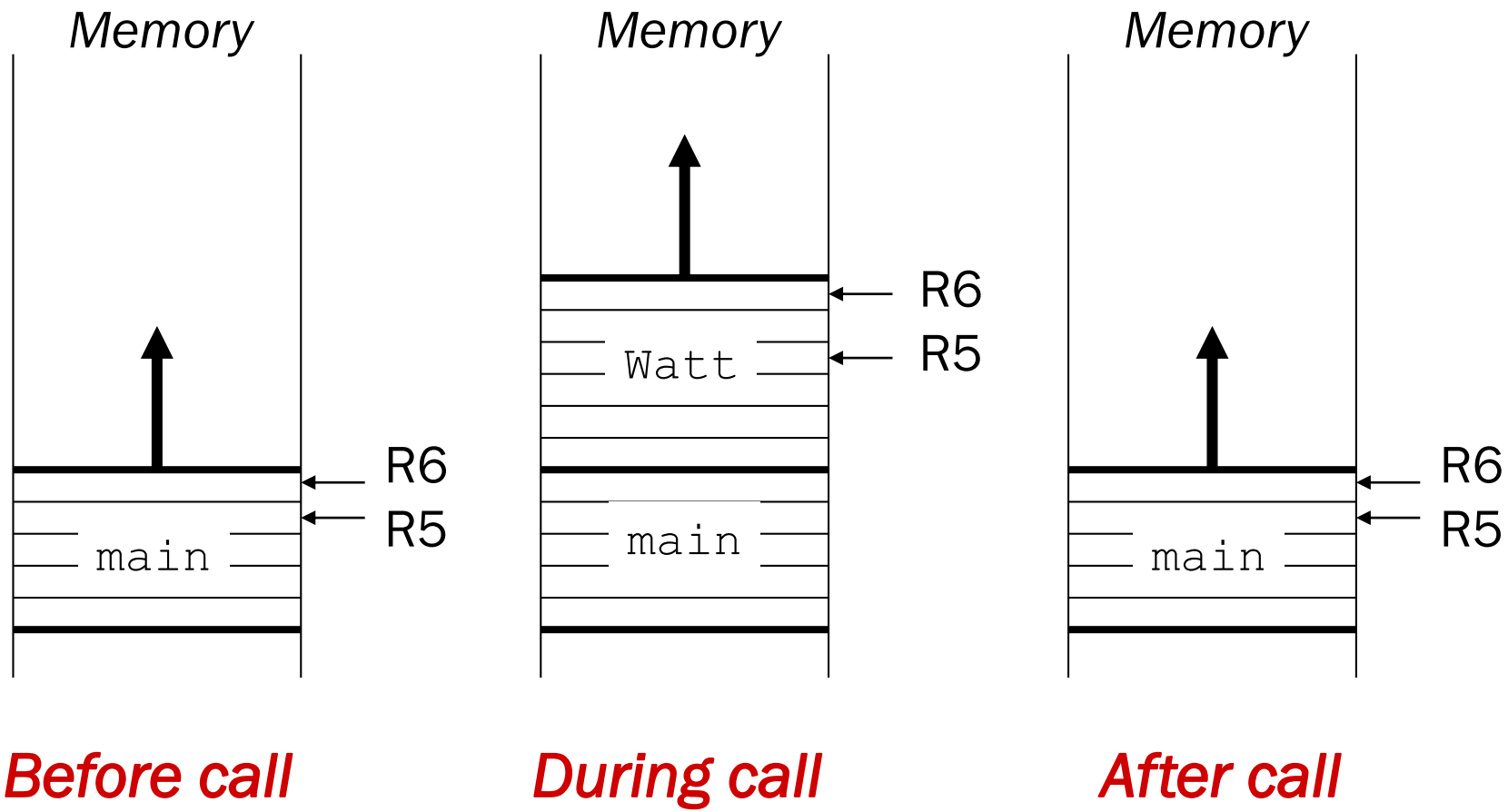
Recall that local variables are stored on the run-time stack in an *activation record*

Frame pointer (R5) points to the beginning of a region of activation record that stores local variables for the current function

When a new function is called, its activation record is pushed on the stack;

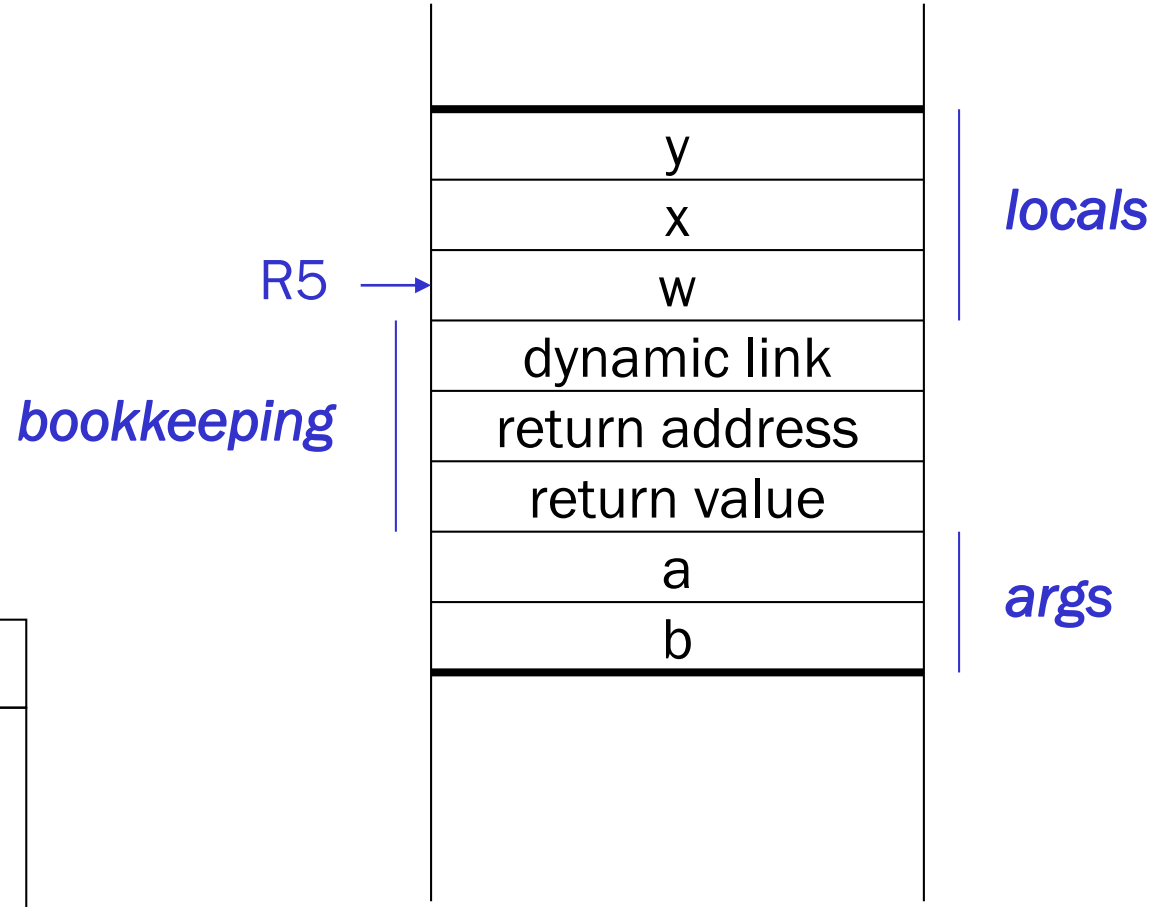
when it returns, its activation record is popped off of the stack.

Run-Time Stack



Activation Record

```
int NoName(int a, int b)
{
   int w, x, y;
   .
   .
   .
   return y;
}
```



Name	Type	Offset	Scope
a	int	4	NoName
b	int	5	NoName
w	int	0	NoName
x	int	-1	NoName
y	int	-2	NoName

Activation Record Bookkeeping

Return value

- space for value returned by function
- allocated even if function does not return a value

Return address

- save pointer to next instruction in calling function
- convenient location to store R7 in case another function (JSR) is called

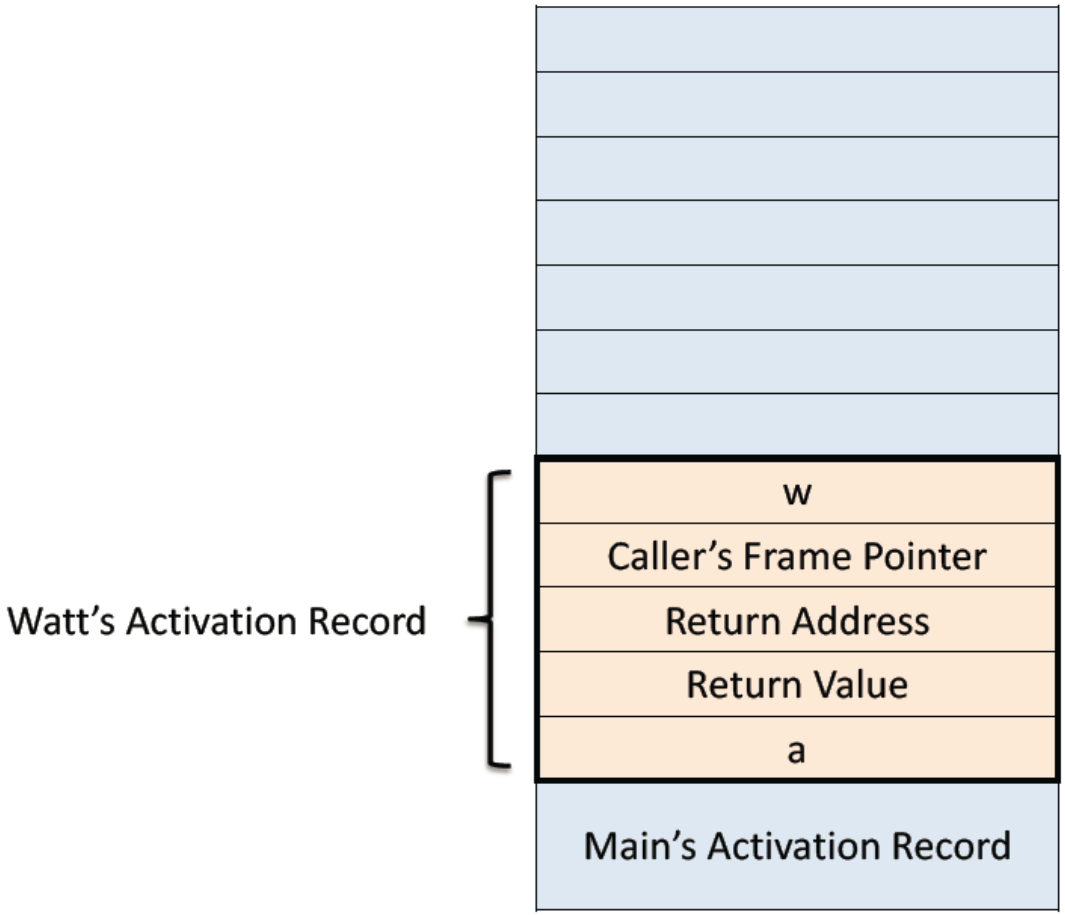
Dynamic link

- caller's frame pointer
- used to pop this activation record from stack

Example Function Call

```
int Volta(int q, int r)
{
   int k;
   int m;
   ...
   return k;
}

int Watt(int a)
{
   int w;
   ...
   w = Volta(w,10);
   ...
   return w;
}
```



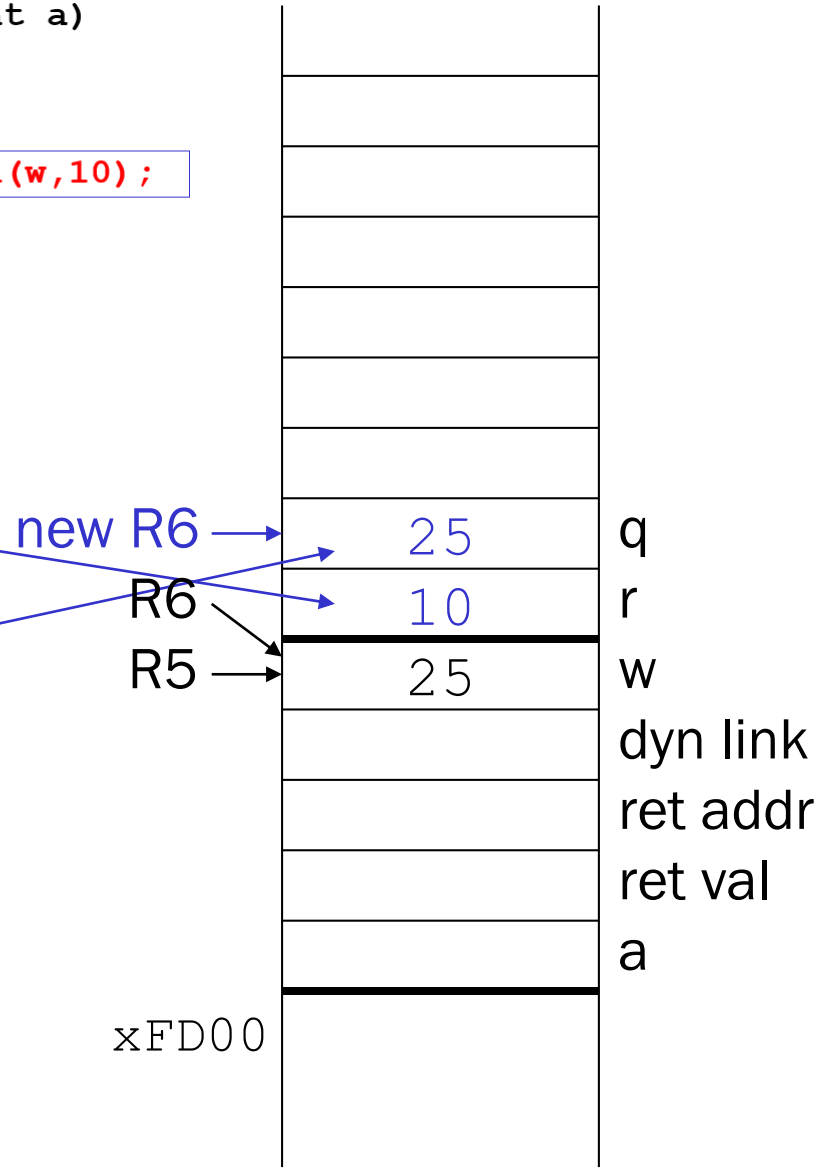
Calling the Function

```
w = Volta(w, 10);
```

```
; push second arg
AND  R0, R0, #0
ADD  R0, R0, #10
ADD  R6, R6, #-1
STR  R0, R6, #0
; push first argument
LDR  R0, R5, #0
ADD  R6, R6, #-1
STR  R0, R6, #0

; call subroutine
JSR  Volta
```

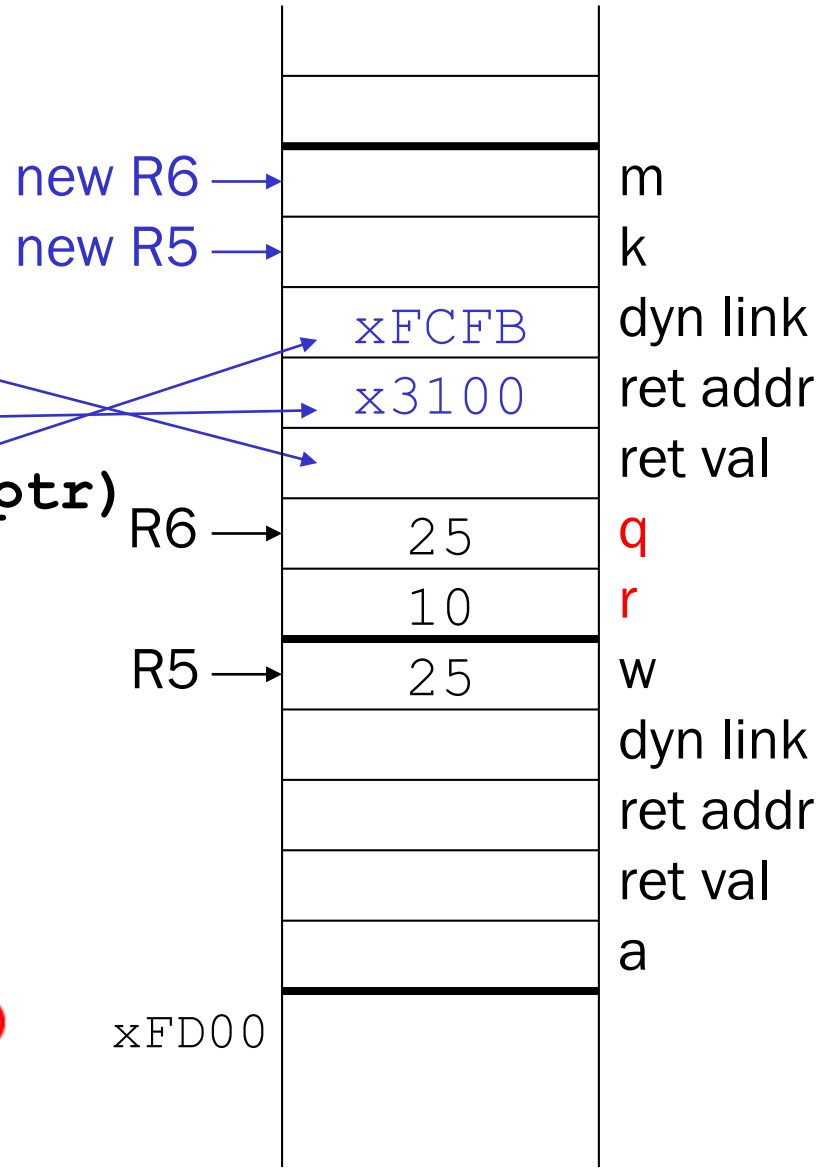
```
int Watt(int a)
{
  int w;
  ...
  w = Volta(w,10);
  ...
  return w;
}
```



Note: Caller needs to know number and type of arguments, doesn't know about local variables.

Starting the Callee Function

```
; leave space for return value
ADD  R6, R6, #-1
; push return address
ADD  R6, R6, #-1
STR  R7, R6, #0
; push dyn link (caller's frame ptr)
ADD  R6, R6, #-1
STR  R5, R6, #0
; set new frame pointer
ADD  R5, R6, #-1
; allocate space for locals
ADD  R6, R6, #-2
```



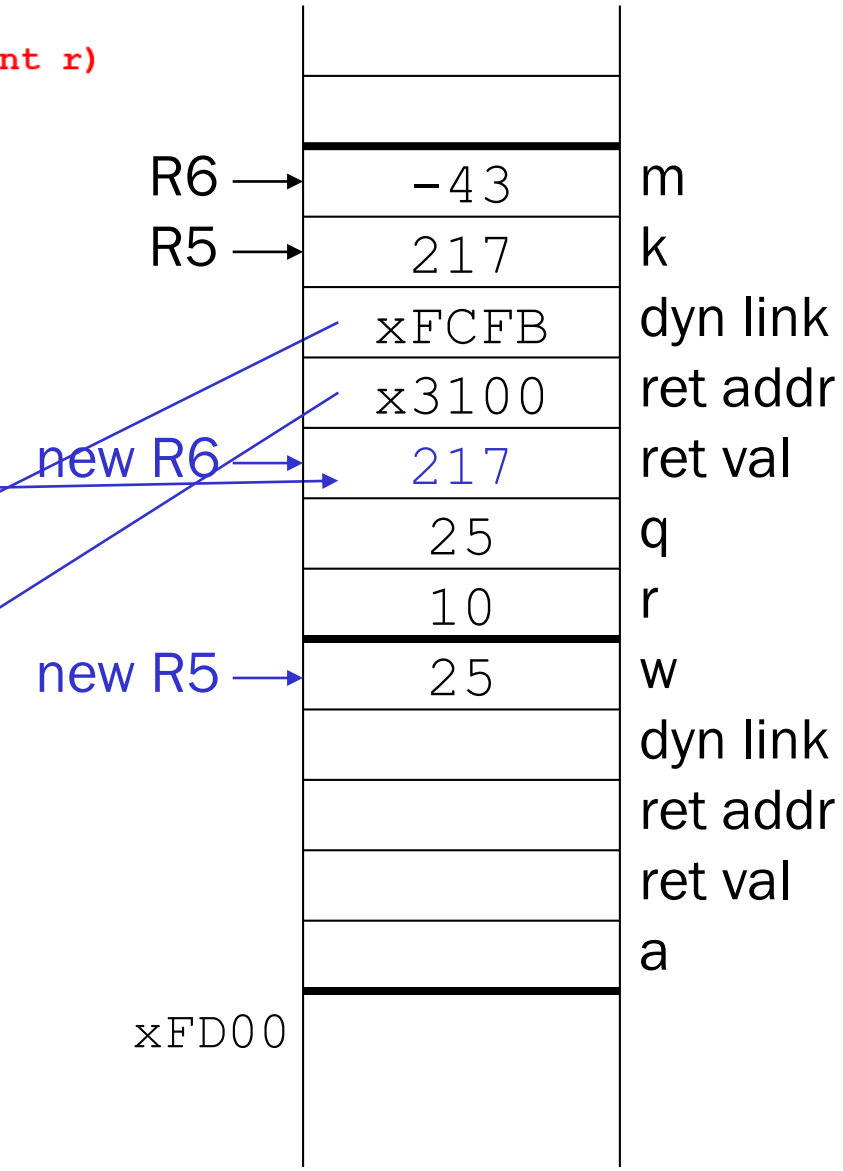

```
int Volta(int q, int r)
{
   int k;
   int m;
   ...
   return k;
}
```

Ending the Callee Function

```
return k;
```

```
int Volta(int q, int r)
{
  int k;
  int m;
  ...
  return k;
}
```

```
; copy k into return value
LDR  R0, R5, #0
STR  R0, R5, #3
; pop local variables
ADD  R6, R5, #1
; pop dynamic link (into R5)
LDR  R5, R6, #0
ADD  R6, R6, #1
; pop return addr (into R7)
LDR  R7, R6, #0
ADD  R6, R6, #1
; return control to caller
RET
```



Resuming the Caller Function

```
w = Volta(w,10);
```

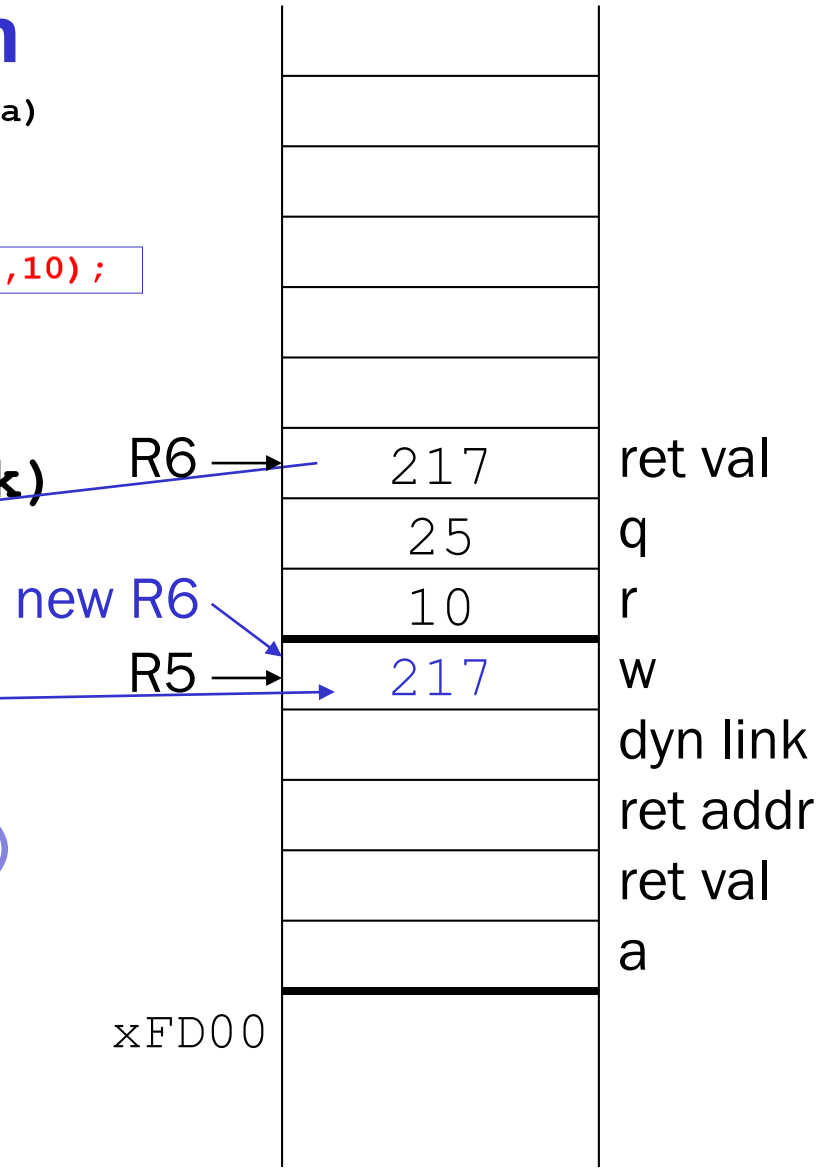
```
int Watt(int a)
{
  int w;
  ...
  w = Volta(w,10);
  ...
  return w;
}
```

```
JSR  Volta

; load return value (top of stack)
LDR  R0, R6, #0
; perform assignment
STR  R0, R5, #0

; pop return value; W=Volta(W,10)
ADD  R6, R6, #1

; pop arguments
ADD  R6, R6, #2
```



Summary of LC-3 Function Call Implementation

1. Caller pushes arguments (last to first).
2. Caller invokes subroutine (JSR).
3. Callee allocates return value, pushes R7 and R5.
4. Callee allocates space for local variables.
5. Callee executes function code.
6. Callee stores result into return value slot.
7. Callee pops local vars, pops R5, pops R7.
8. Callee returns (JMP R7).
9. Caller loads return value and pops arguments.
10. Caller resumes computation…

Run-Time Stack Exercise

Adopted from Prof. Yuting's lecture notes

```
#include <stdio.h>
int Fact(int n);

/* main function */
int main() {
    int number;
    int answer;

    printf("Enter a number: ");
    scanf("%d", &number);
    answer = Fact(number);
    printf("factorial of %d is %d\n", number, answer);
    return 0;
}
```

```
/* Function definition of Factorial function */
int Fact(int n) {
    int i, result=1;

    for (i = 1; i <= n; i++)
        result = result * i;

    return result;
}
```

x3FF0	
x3FF1	
x3FF2	
x3FF3	
x3FF4	
x3FF5	
x3FF6	
x3FF7	
x3FF8	
x3FF9	
x3FFA	
x3FFB	
x3FFC	
x3FFD	
x3FFE	
x3FFF	answer
x4000	number