Today's Topics

Last Time

- Abstract machines, run time models
- Expression stack (ES) model of expression evaluation
- Run stack (RS) model of scopes and automatic variables
- Managing the Run Stack - the Dynamic Pointer Stack, the Run Stack Display, (LL,ON) addressing
- Maintaining the Display, value and reference parameters

Today

- Modelling procedures and functions

Then

- Modelling storage layout of arrays and records
- What is Semantic Analysis?

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Runtime Model - Procedures

- We normally enter new scopes by calling a procedure or function
- So far, we have described the representation of the new scope, but not the details of how it is constructed
- We can divide the procedure or function call into two components - the *caller setup*, and the *callee prologue*
- In the caller setup, we are interested in setting up the parameters and making the actual call to transfer control to the procedure (the *callee*)
- In the callee prologue, we are interested in establishing the storage and setup of the procedure's new scope

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Procedures - Caller Setup

- Since parameters are treated as the first variables of the new scope, we have to remember where the top of the RS was when we started pushing parameters
- In our abstract machine, a new instruction called *markstack* is used for this purpose
- *Markstack* copies the current value of the runstack pointer to a temporary "register" of the machine
- We must also remember the location in the code to return to after the call - this involves yet another stack called the *return stack*

p (a, b) →

```
19: markstack
20: push  a
21: passparameter
22: push  b
23: passparameter
24: call  p
25:  ...
```


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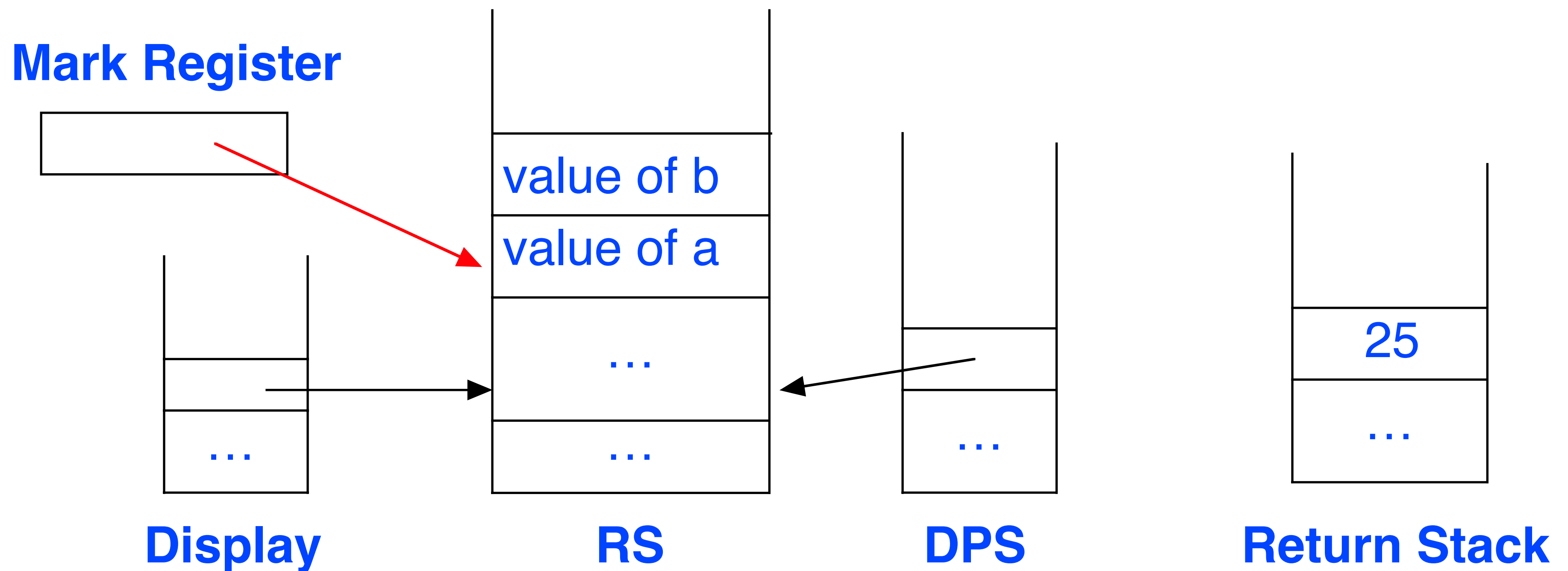
Procedures - Caller Setup

p (a, b) →

```
19: markstack
20: push   a
21: passparameter
22: push   b
23: passparameter
24: call   p
25:  ...
```



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Procedures - Callee Prologue / Epilogue

- The procedure's *prologue* is responsible for completing the setup of the Run Stack, Display and Dynamic Pointer Stack, and its *epilogue* is responsible for undoing it

- In our abstract machine, the single new instruction *enter* handles the prologue, and the new abstract machine instruction *return* handles the epilogue and returns control to the caller

- Each of these takes as operand the lexical level of the procedure (so they know which Display entry to modify), and the number of local variables (so *enter* knows how much storage to reserve on the Run Stack for the procedure's scope)

```
procedure p (a,b);         p:     enter    LL,Nlocals
   ...                             ...
end p;                            return   LL
```


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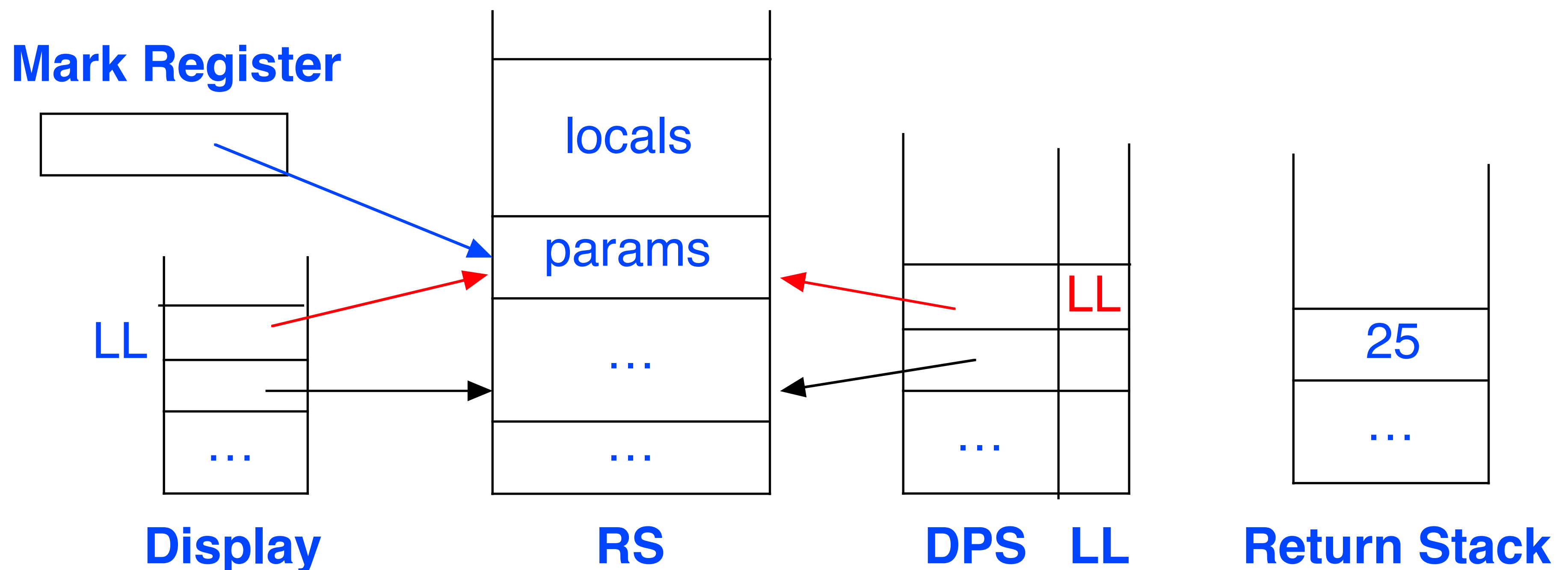
Procedures - Callee Prologue / Epilogue

- What exactly does the *enter* instruction do?

DPSPointer += 1	*push DPS frame*
DPS[DPSPointer].RSPointer := MarkReg	
DPS[DPSPointer].LL := LL	
Display[LL] := MarkReg	*set Display[LL]*
RSPointer+= Nlocals	*allocate space for local vars*



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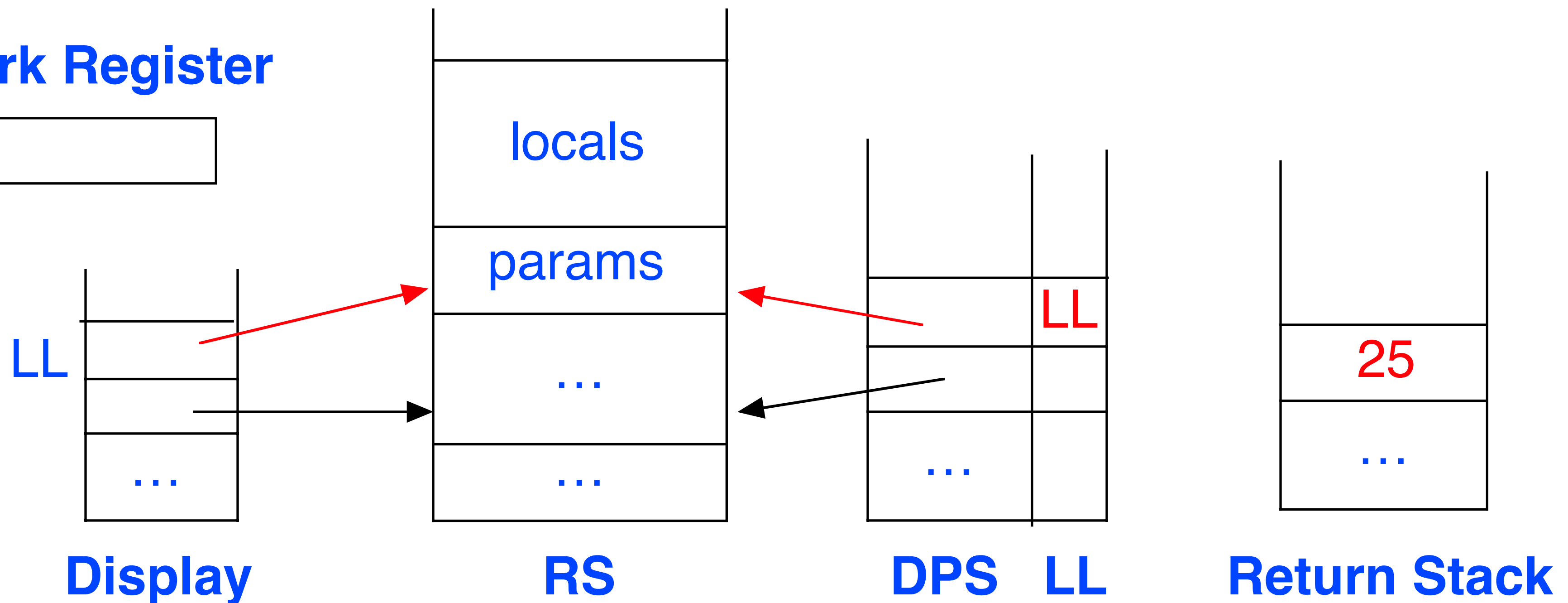
Procedures - Callee Prologue / Epilogue

- The *return* instruction undoes all this and returns control to the caller

RSPointer := DPS[DPSPointer].RSPointer - 1	*pop DPS frame*
DPSPointer -= 1	
Display[LL] := DPSSearch(DPS,DPSPointer,LL)	*reset Display*
PC := ReturnStack (RetPointer)	*back to caller*
RetPointer -= 1	



Function Results

- Function results are normally returned by pushing their value on the ES - this is the right place for them, since the result of a function is a value to be used in an expression

```
function f(x) : integer;
    ...
  return x;                               push     x
    ...                                   return   LL
```

- This also works for returning objects in OO languages, except that we would push a reference (address) of the returned object on the ES

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Function Results

- In some languages (e.g., Turing, Ada, Modula 3), it is possible to return entire arrays as values (not objects or references to them, but a copy of the whole thing)

- This can be handled by creating a local array in the *caller* to receive the result, and then passing it by reference to the function

```
function p(a:int): array 1..100 of int

bar := p(1)[i]  =>
                   var presult: array 1..100 of int
                   p (1, presult)
                   bar := presult[i]
```


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Summary

Procedures and Functions

- Caller setup, prologue and epilogue
- Returning function results

Next Week

- Quiz #2: Lexical and syntactic structure, grammars, PDA and BNF, bottom-up and top-down parsing, ambiguity, runtime model of expressions
- Text chapters 7 - 11 inclusive (lectures 8 - 13, to end of ES)

Then

- Storage layout model
- Begin Semantic Analysis

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