CC Lecture 12

Prepared for: 7th Sem, CE, DDU

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Runtime Environment

(topics covered so far)

- Parameter passing methods
- Static storage allocation
- Dynamic stack storage allocation
  - Activation record structure
  - Offset calculation for overlapped storage

Allocation of nested procedure

```
program RTST;
    procedure P;
        procedure Q;
            begin R; end
        procedure R;
            begin Q; end
    begin R; end
begin P; end
```

- P is nested in RTST
- Q and R are nested in P
- Q and R are at same level
- Q calls R and R calls Q
- P calls R
- Main program RTST calls P

Allocation of nested procedure

```
program RTST;
    procedure P;
        procedure Q;
            begin R; end
        procedure R;
            begin Q; end
    begin R; end
begin P; end
```

- Activation records are created at procedure entry time and are destroyed at exit time
- How to access variables declared in various procedures?

Allocation of nested procedure

program *RTST;*

procedure *P;*

procedure *Q;*

begin *R; end*

procedure *R;*

begin *Q; end*

begin *R; end*

begin *P; end*

- **Call sequence**

  RTST -> P -> R -> Q -> R

- Main program RTST cannot access variables of P,Q and R.
- P can access its own and main program variables but not of Q and R
- Q cannot access variables of R but can access variables of P and main
- R cannot access variables of Q but can access variables of P and main

Allocation of nested procedure

program *RTST;*

procedure *P;*

procedure *Q;*

begin *R; end*

procedure *R;*

begin *Q; end*

begin *R; end*

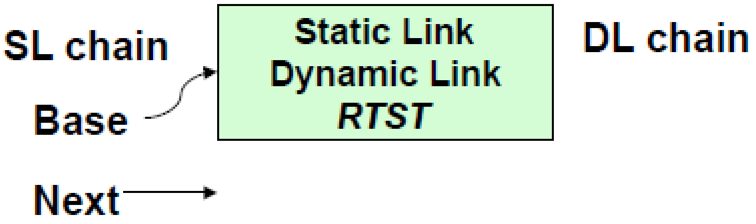
begin *P; end*

- **Call sequence**

  RTST -> P -> R -> Q -> R

- When P is called, activation record of P is made
- Base pointer + offset can be used to access local variables of P
- But what about variables of main??
- Can base pointer be use in this case??

Allocation of nested procedure



program *RTST;*

procedure *P;*

procedure *Q;*

begin *R; end*

procedure *R;*

begin *Q; end*

begin *R; end*

begin *P; end*

- **Call sequence**

  RTST -> P -> R -> Q -> R

- The **DL chain** chains all the activation records in order to maintain a stack structure.
- To access the variables of RTST, the **SL field** of the activation record has to be put into a register, and the contents of that activation of that register will now point to the beginning of the activation record for RTST.
- Consider this particular value and then access the variables of RTST using the offset.

Allocation of nested procedure

program *RTST;*

procedure *P;*

procedure *Q;*

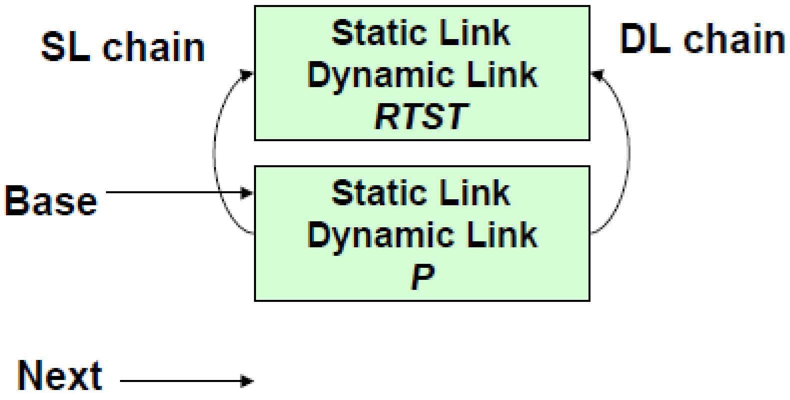
begin *R; end*

procedure *R;*

begin *Q; end*

begin *R; end*

begin *P; end*



For variables of RTST:
SL field of P → register → beginning of RTST + offset

For variables of P:
Base is beginning of P + offset

- **Call sequence**

  RTST -> P -> R -> Q -> R

Allocation of nested procedure

program *RTST;*

procedure *P;*

procedure *Q;*

begin *R; end*

procedure *R;*

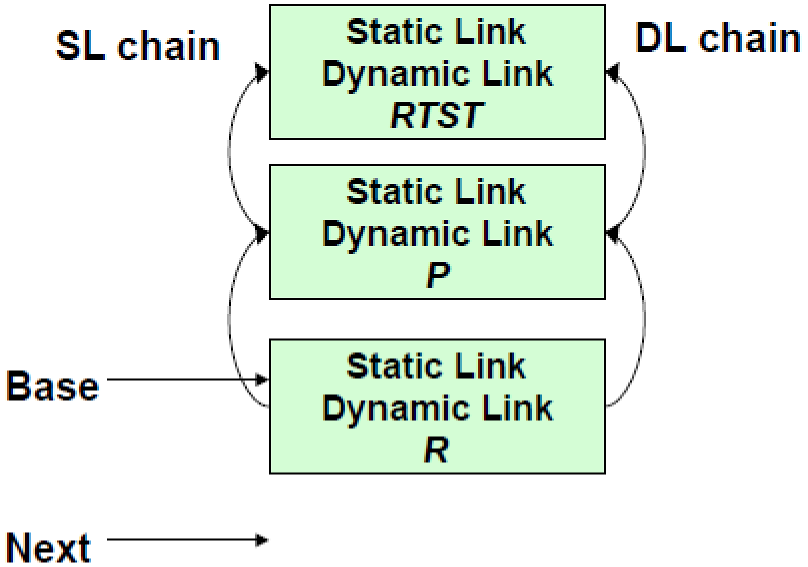
begin *Q; end*

begin *R; end*

begin *P; end*

- **Call sequence**

  RTST -> P -> R -> Q -> R



For variables of R: Base

For variables of P: use SL

For variables of RTST: one more level of indirection using SL

Allocation of nested procedure

program *RTST;*

procedure *P;*

procedure *Q;*

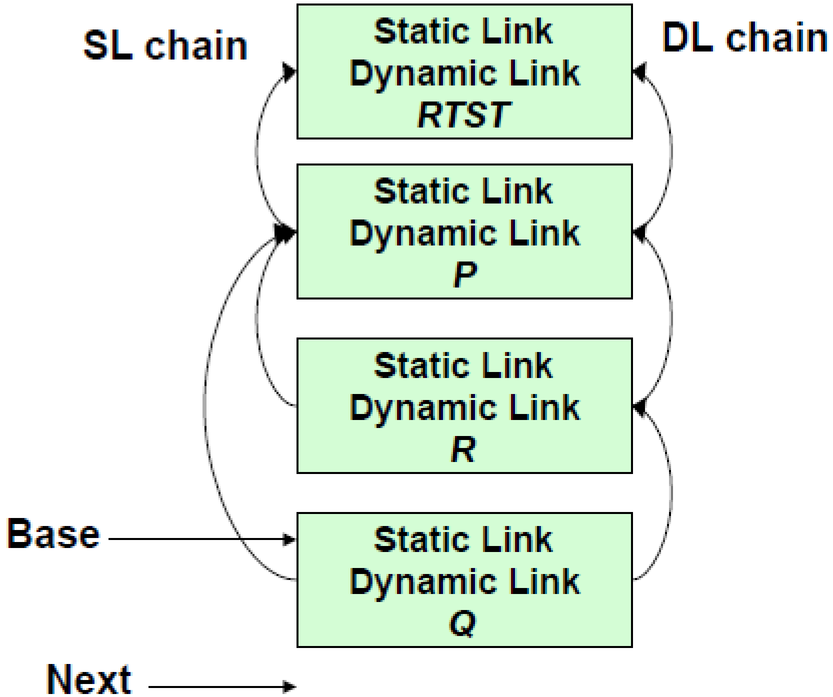
begin *R; end*

procedure *R;*

begin *Q; end*

begin *R; end*

begin *P; end*



- **Call sequence**

  RTST -> P -> R -> Q -> R

No static link from Q→R, as Q cannot access variables of R

But SL from Q→P, as Q can access variables of P and RTST

Allocation of nested procedure

program *RTST;*

procedure *P;*

procedure *Q;*

begin *R; end*

procedure *R;*

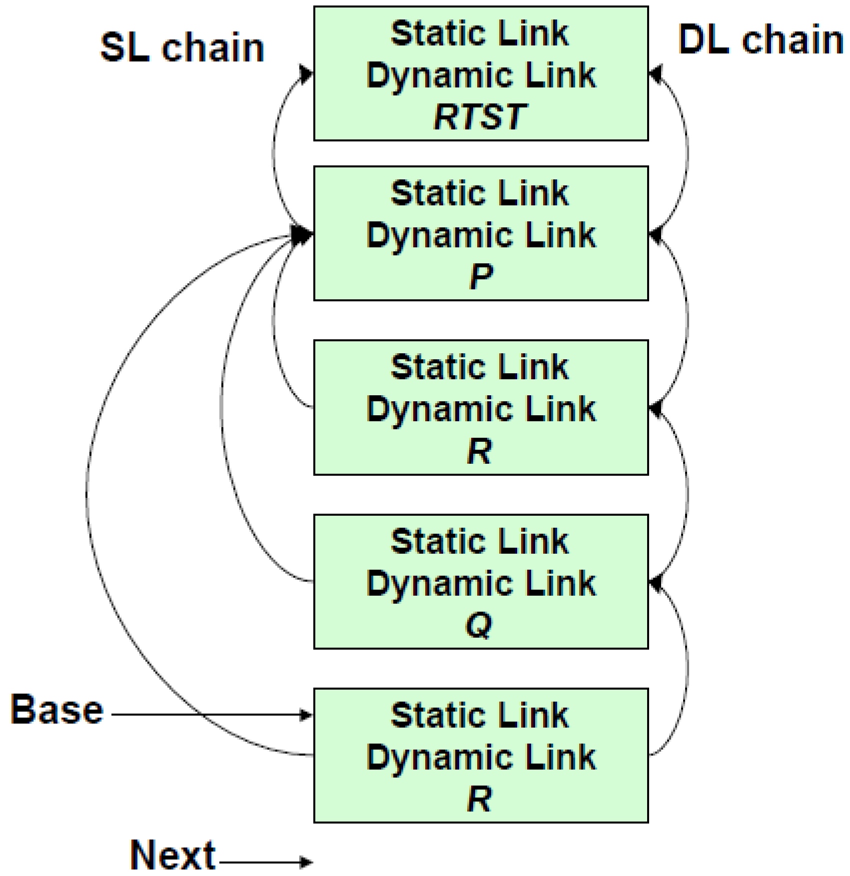
begin *Q; end*

begin *R; end*

begin *P; end*

- **Call sequence**

  RTST -> P -> R -> Q -> R



No SL: R→Q and R→R

Allocation of nested procedure

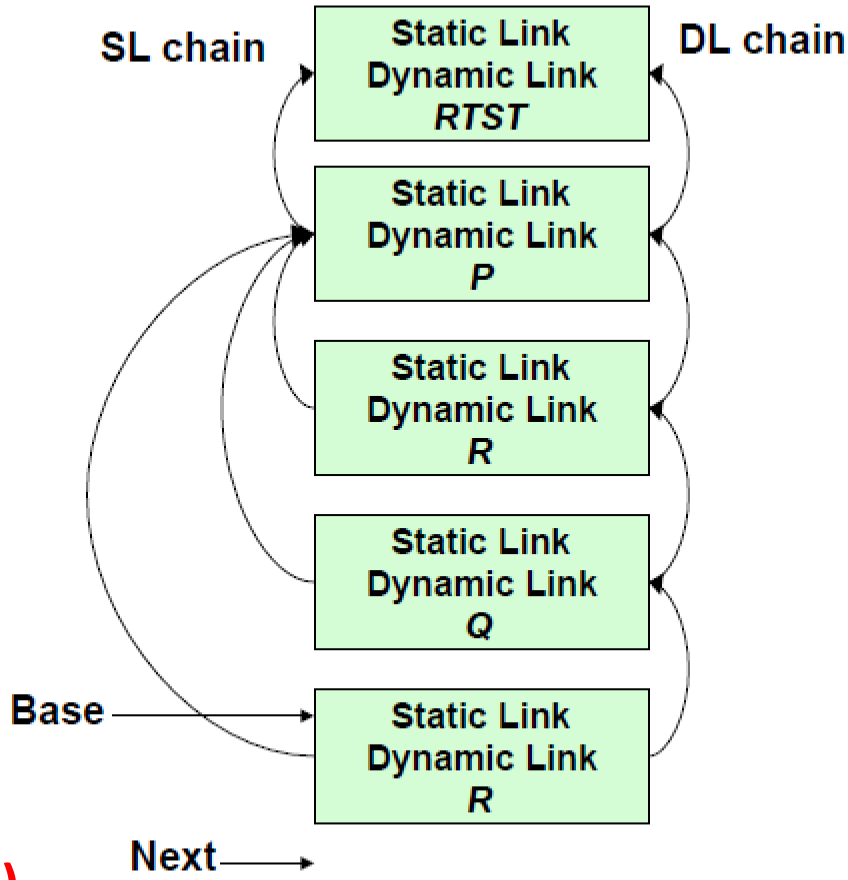
1. program *RTST;*
2. procedure *P;*
3. procedure *Q;*
   begin *R; end*
3. procedure *R;*
   begin *Q; end*

begin *R; end*

begin *P; end*

- **Call sequence**

RTST(1) -> P(2) -> R(3) -> Q(3) -> R(3)



Allocation of nested procedure

How SL is determined?

- Skip **L1 - L2 + 1** records starting from the caller's AR and establish the static link to the AR reached
- L1=caller and L2=Callee

RTST(1) → P(2) → R(3) → Q(3) → R(3)

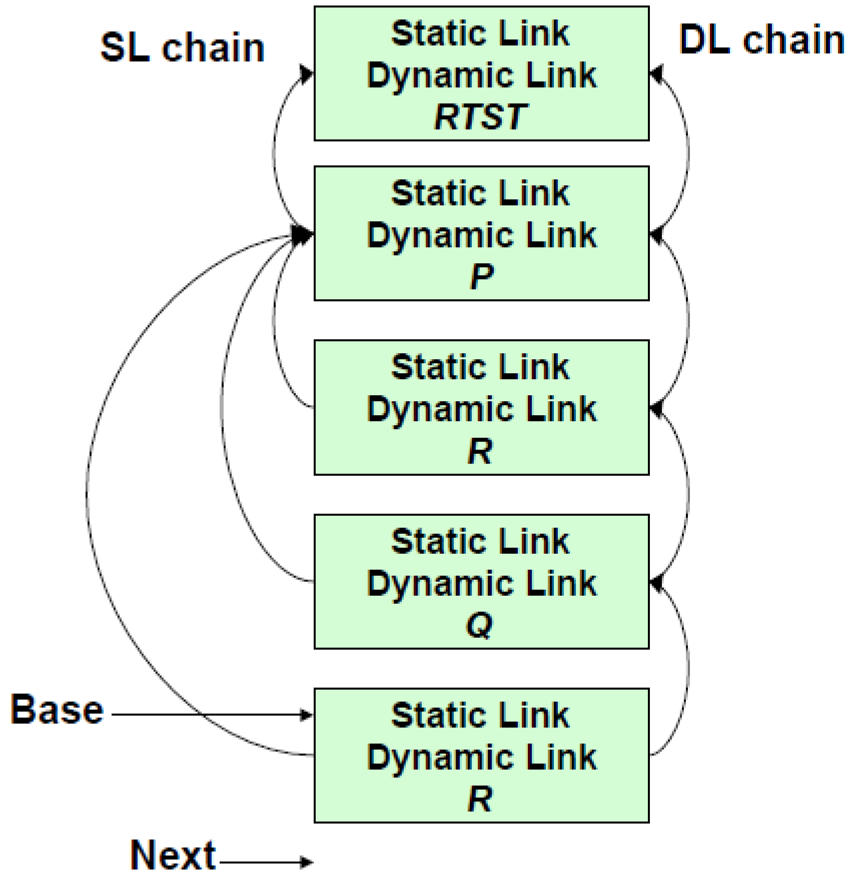
- for **P(2)→R(3),** 2 – 3 + 1 = 0;

  hence the SL of R points to P
- for **R(3)→Q(3),** 3 – 3 + 1 = 1;

  skipping 1 link starting from R,

  we get P;

  SL of Q points to P



Creation of activation record happens in callee code

- The creation of activation record takes place after the callee assumes control, because the exact size of the activation record will be known to the callee function.
- It will not be known to the caller.
- Callee functions can possibly be compiled separately.
- So, the total area for the variables of the function, its temporaries will not be known to the caller.
- Callers will only the size of the parameter list.
- So, the complete creation of the activation record really happens in the callee code.

Allocation of nested procedure

program *RTST;*

procedure *P;*

procedure *Q;*

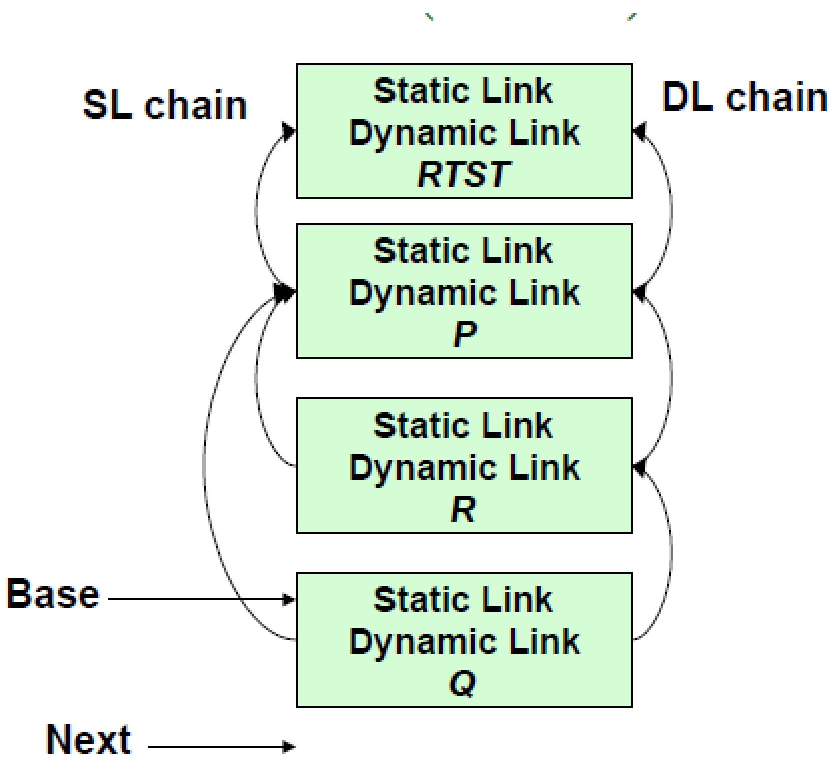
begin *R; end*

procedure *R;*

begin *Q; end*

begin *R; end*

begin *P; end*



- **Call sequence**

RTST -> P -> R -> Q ← R **Return from R**

Allocation of nested procedure

program *RTST;*

    procedure *P;*

        procedure *Q;*

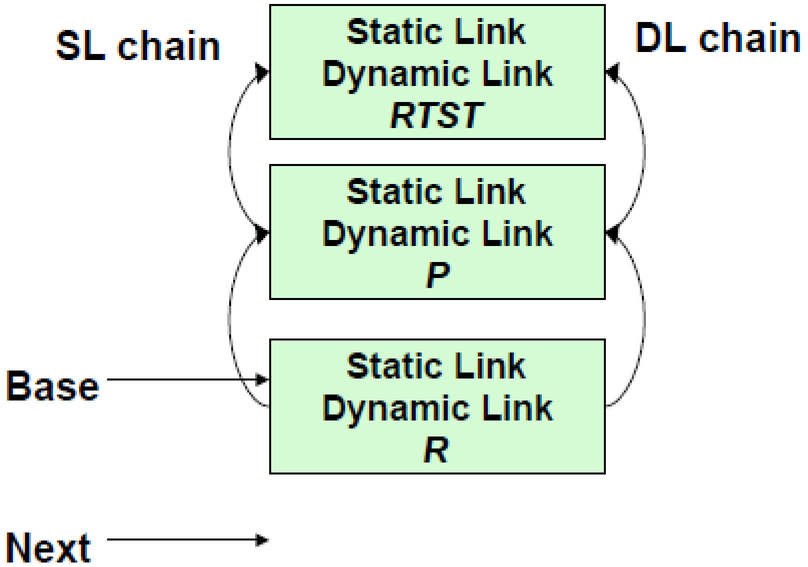
            begin *R; end*

        procedure *R;*

            begin *Q; end*

    begin *R; end*

begin *P; end*



- **Call sequence**

RTST -> P -> R ← Q

Return from Q

Allocation of nested procedure

program *RTST;*

procedure *P;*

procedure *Q;*

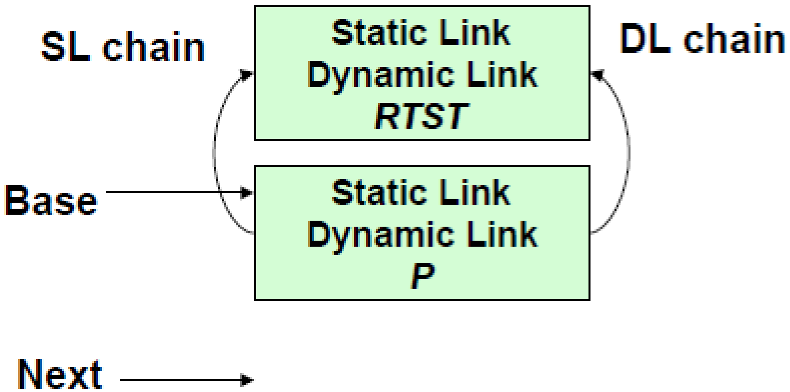
begin *R; end*

procedure *R;*

begin *Q; end*

begin *R; end*

begin *P; end*



- **Call sequence**

RTST -> P ← R **Return from R**

Allocation of nested procedure

program *RTST;*

procedure *P;*

procedure *Q;*

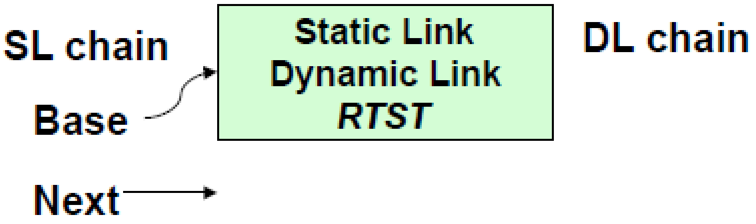
begin *R; end*

procedure *R;*

begin *Q; end*

begin *R; end*

begin *P; end*



- **Call sequence**

RTST ← P

Return from P

Static vs. Dynamic link

- **Static link:**
  - to access the global variables in the various activation records.
- **Dynamic link:**
  - to maintain the stack of activation records.

Display Stack

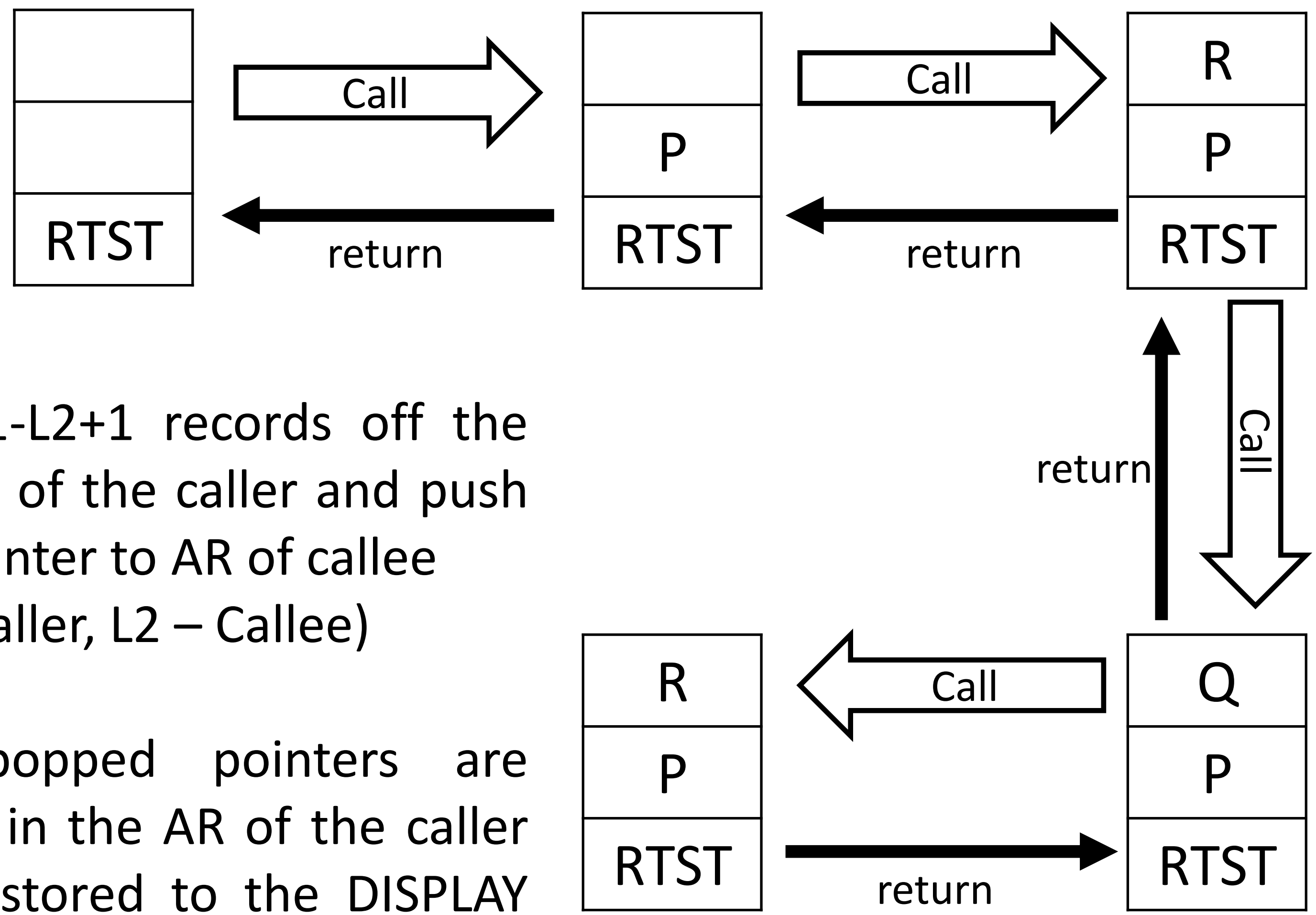
- It is **data structure** to be used instead of **static link**.

- A stack of pointers which point to the activation records of procedures which are right now executing is maintained instead of static link.

- The most recent procedure which is activated its activation record pointer is on the top of the stack.

- The display stack structure must reflect the scope of the various functions and procedures appropriately.

Display Stack of Activation Records (without SL)



Pop L1-L2+1 records off the display of the caller and push the pointer to AR of callee
(L1 – caller, L2 – Callee)

The popped pointers are stored in the AR of the caller and restored to the DISPLAY after the callee returns

What about languages that don't support nested procedures?

- Example:- C language
- No requirement for static link
- Two links are needed
  1. To the beginning of the activation record
  2. To the static area containing global variables
- Dynamic link structure will handle the allocation and deallocation of the stack.

Static (lexical) scope	Dynamic scope
C, C++, Java, Pascal, Python	Lisp, Perl, Logo, LaTeX
The name resolution depends on the location in the source code and the lexical context, which is defined by where the named variable or function is defined.	The name resolution depends upon the program state when the name is encountered which is determined by the execution context or calling context.
A global identifier refers to the identifier with that name that is declared in the closest enclosing scope of the program text.	A global identifier refers to the identifier associated with the most recent activation record.
Uses the static (unchanging) relationship between blocks in the program text.	Uses the actual sequence of calls that are executed in the dynamic (changing) execution of the program.

Example 1 (C-like structure is used)

```
int x = 1, y = 0;
int g(int z){
    return x+z;
}
int f(int y) {
    int x;
    x = y+1;
    return g(y*x);
}
y = f(3);
```

After the call to g

Static scope

x = 1

So, y = 1+ 12 = **13**

Dynamic scope

x = 4

So, y = 4 + 12 = **16**

outer block

x	1
y	0

f(3)

y	3
x	4

g(12)

z	12

Stack of activation records after the call to *g*

Example 2 (C-like structure is used)

```
float r = 0.25;
void show() {
     printf("%f",r);
}
void small() {
     float r = 0.125;
     show();
}

int main (){
     show();
     small();
     printf("\n");
     show();
     small();
     printf("\n");
}
```

Output Static Scope	**Output Dynamic Scope**
?	?

Example 2 (C-like structure is used)

```
float r = 0.25;
void show() {
    printf("%f",r);
}
void small() {
    float r = 0.125;
    show();
}
```

```
int main (){
    show();
    small();
    printf("\n");
    show();
    small();
    printf("\n");
}
```

Output Static Scope	Output Dynamic Scope
0.25 0.25 0.25 0.25	0.25 0.125 0.25 0.125

Implementing Dynamic scope

1. Deep access method

2. Shallow access method

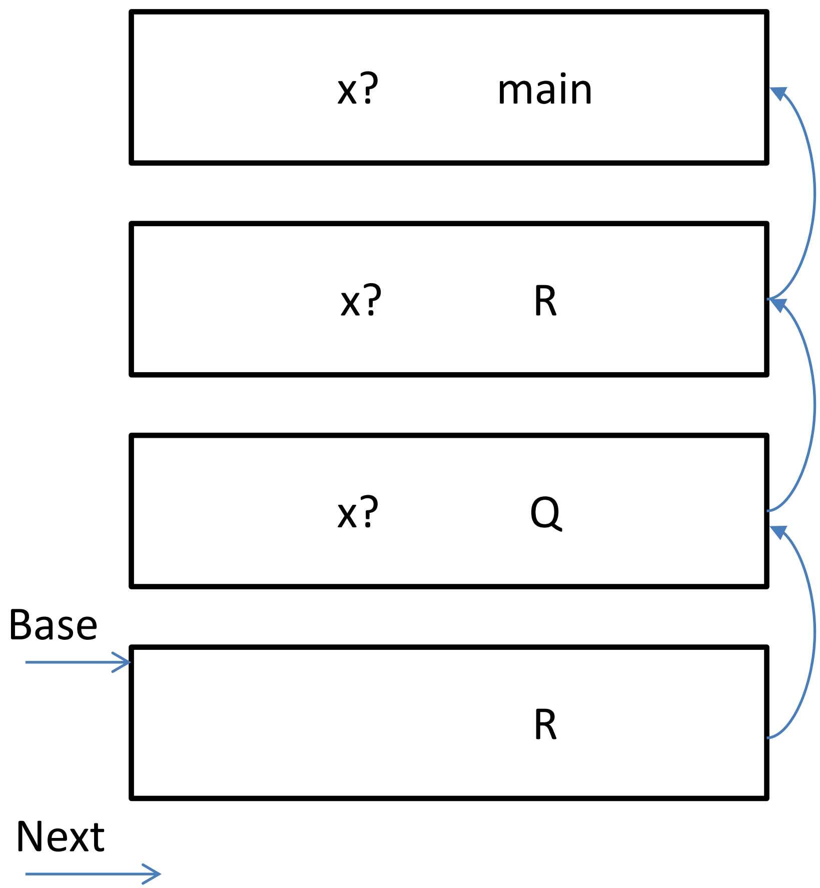
Deep Access Method

- The idea is to keep a stack of active variables.
- Use control links instead of access links and to find a variable, search the stack from top to bottom looking for most recent activation record that contains the space for desired variables.
- Since search for nonlocal variables is made “deep” in the stack, the method is called deep access.
- Here, a symbol table should be used at runtime.

Shallow Access Method

- The idea is to keep a central storage and allot one slot for every variable name.
- If the names are not created at runtime then the storage layout can be fixed at compile time.
- Else, when new activation procedure occurs, then that procedure changes the storage entries for its local at entry and exit.
- Shallow access allows fast access but has a overhead of handling procedure entry and exit.

Deep Access Example



Calling Sequence
Main → R → Q → R

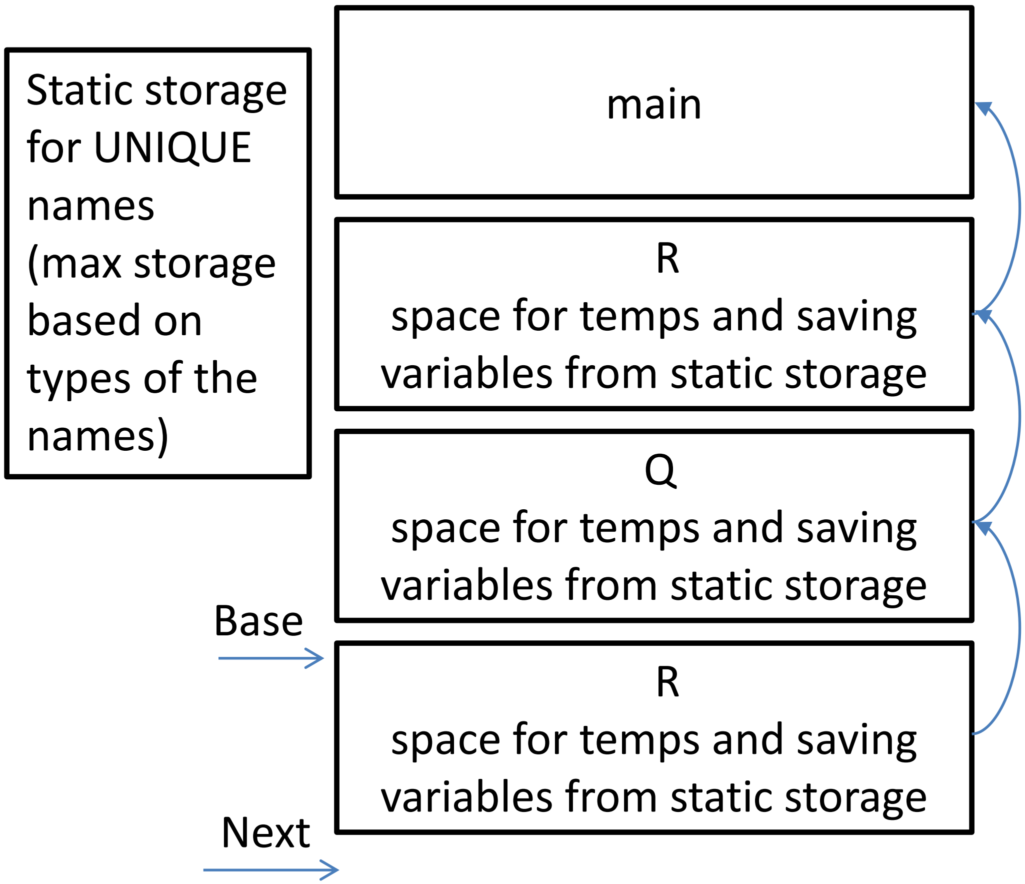
Currently, R is being accessed. (Base)

In R, if we don't find x, we search in Q then again R and then in main.

Deep Access Method

- Dynamic link is used as static link.
- Activation records are searched on the stack to find the first activation record containing the non-local name to be found.
- The time required to access global variables is much more than the time required to access local variables.
- The time to access a global variable will depend on the sequence of calls that are made (hence can’t be determined at compile-time).
- Needs some information on the identifiers to be maintained at runtime within the ARs.

Shallow Access Example



Calling Sequence
Main → R → Q → R

Direct and quick access to global variables, but some overhead is incurred when activations begin and end.

Shallow Access Method

- Variables declared in the procedures are stored in a unique static storage area.
- There is exactly one fixed amount of storage for each unique name.
- If same name is declared in various procedures with different type then maximum storage required of the given types is allocated in the static storage area.
- The advantage is every name has a unique address and it is static so there is no need to use a stack pointer to access.
- But, there is an overhead of storing and restoring at begin and end of the activation record.

Runtime Environment

- Parameter passing methods
- Static storage allocation
- Dynamic stack storage allocation
  - Activation record structure
  - Offset calculation for overlapped storage
  - **Allocation of nested procedure**
  - **Display stack structure (without static link)**
  - **Static and Dynamic scope**
    - **Deep Access Method for dynamic scope**
    - **Shallow Access Method for dynamic scope**