Pointers

- ✦ References:

  Programmer's Guide to Fortran 90. Brainerd Goldberg and Adams

  Fortran 90 Handbook. Adams et al.

- ✦ What are Fortran pointers?
  - A pointer variable can be though of as an alias for another variable.
  - They are a descriptor listing the attributes of the objects (targets) that the pointer may point to, and the address, if any, of a target. They also encapsulate the lower and upper bounds of array dimensions, strides and other metadata.
  - They have no associated storage until it is allocated or otherwise associated.

- A pointer variable can be of any type
- A pointer is a variable that has been given the ***pointer*** attribute.
- A variable aliased or "pointed to" by a pointer must have the ***target*** attribute
- For Example

```
REAL,POINTER :: ptr
REAL,TARGET :: x

x = 4.7
ptr => x
print *, ptr
x = 8.3
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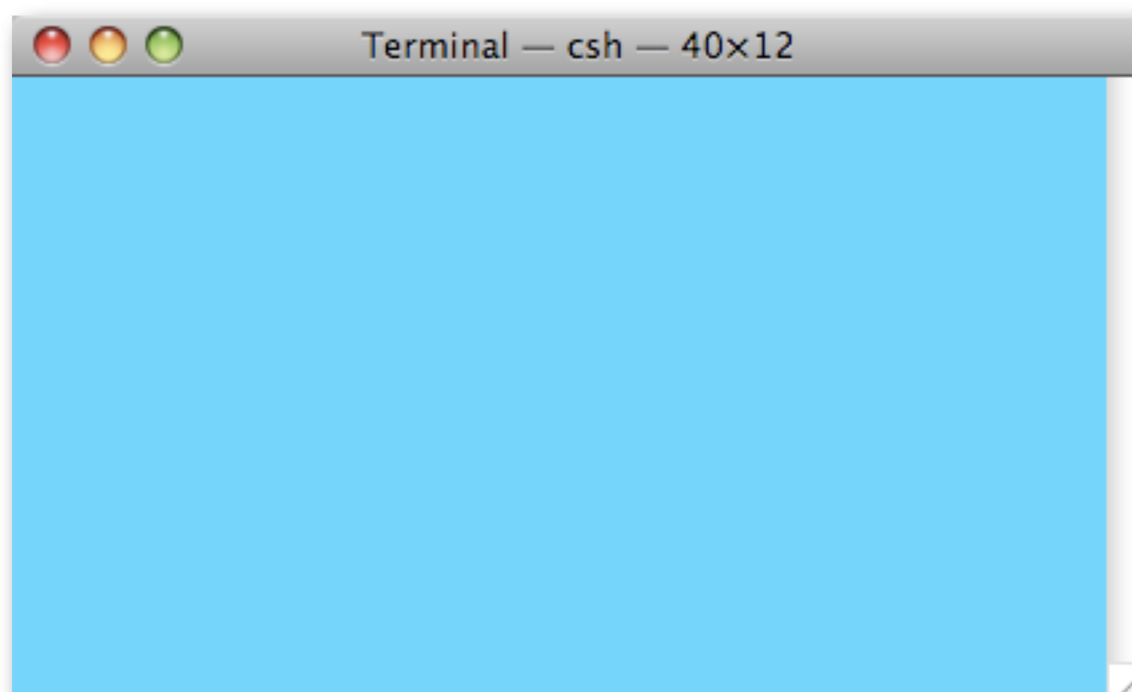

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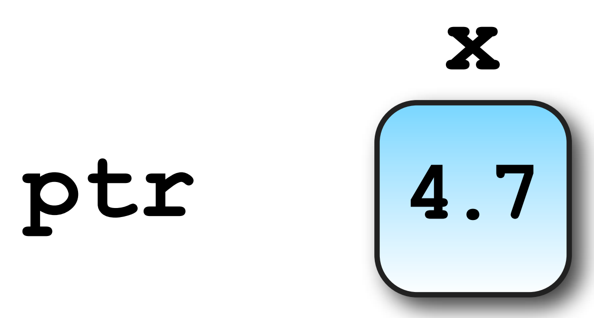

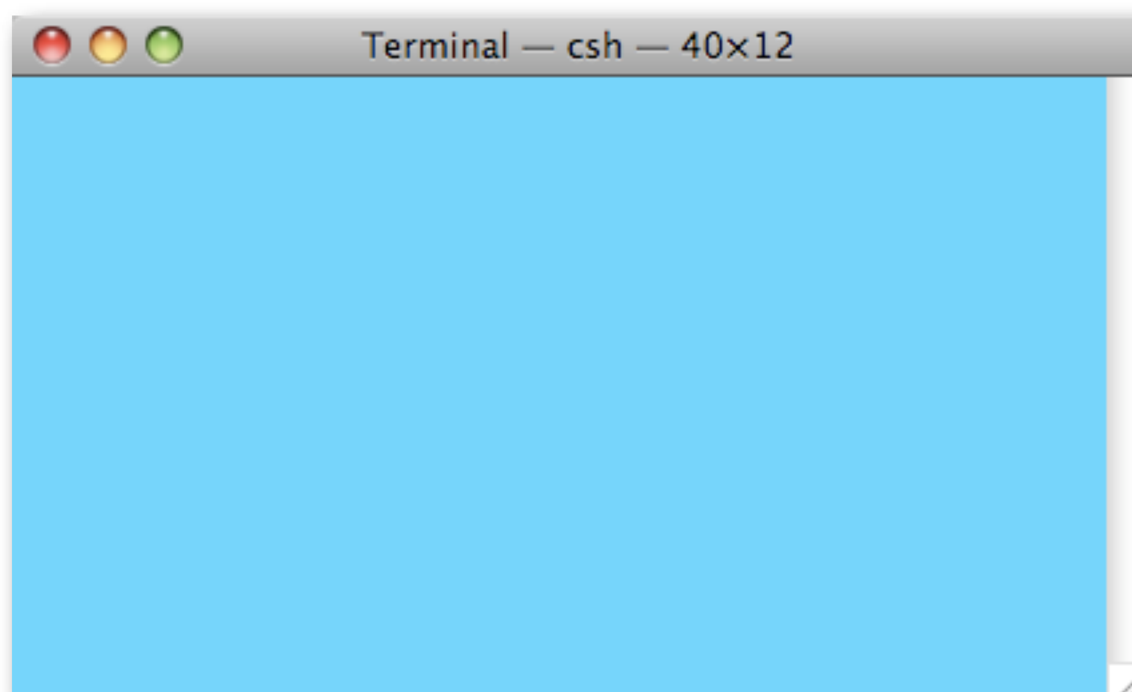

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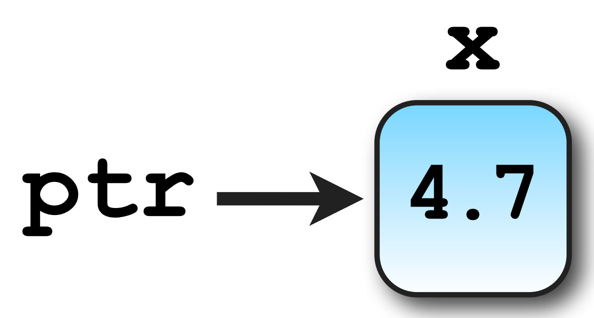

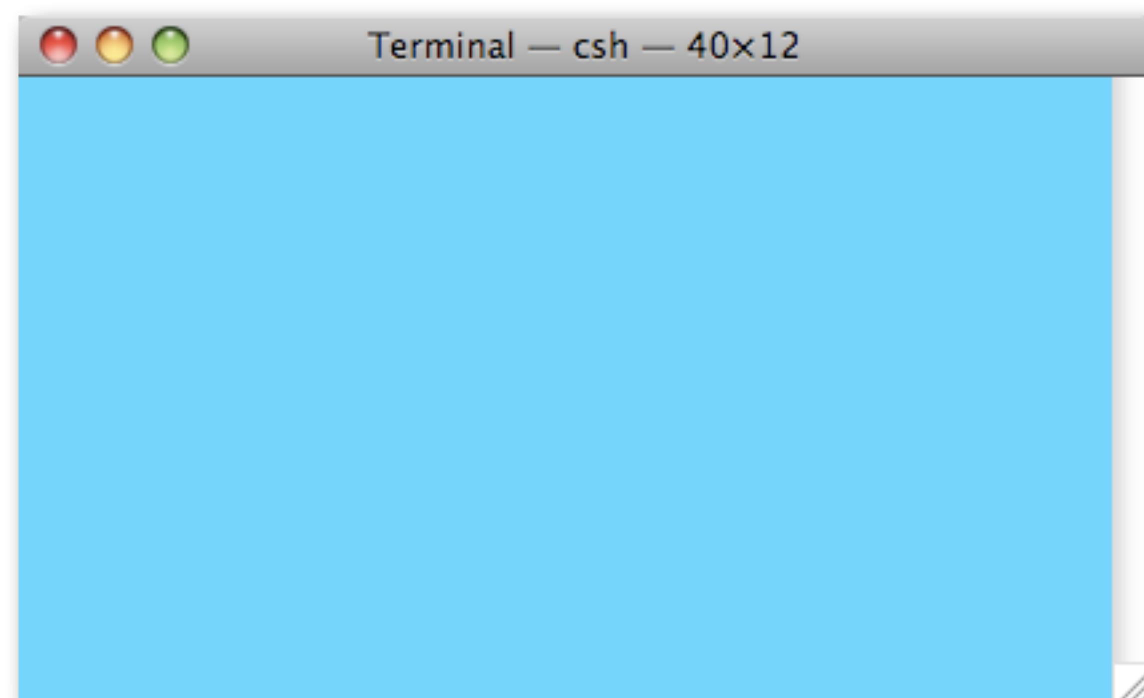

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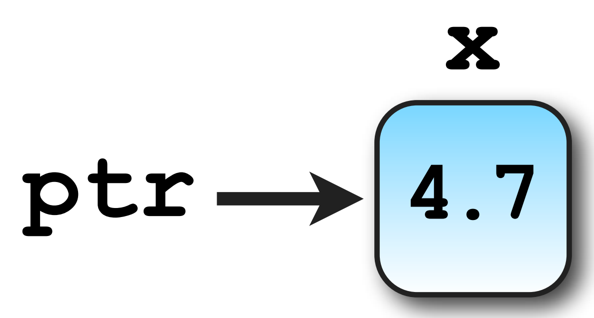

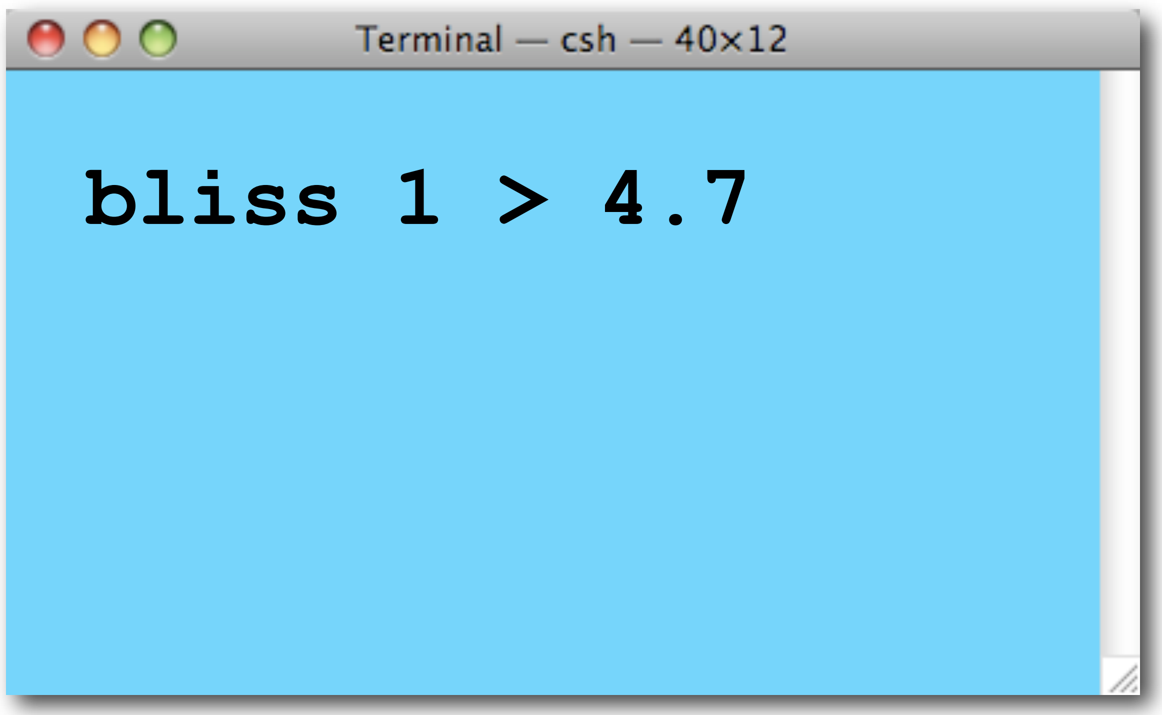

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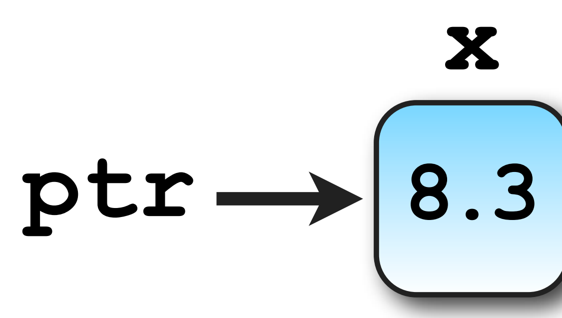


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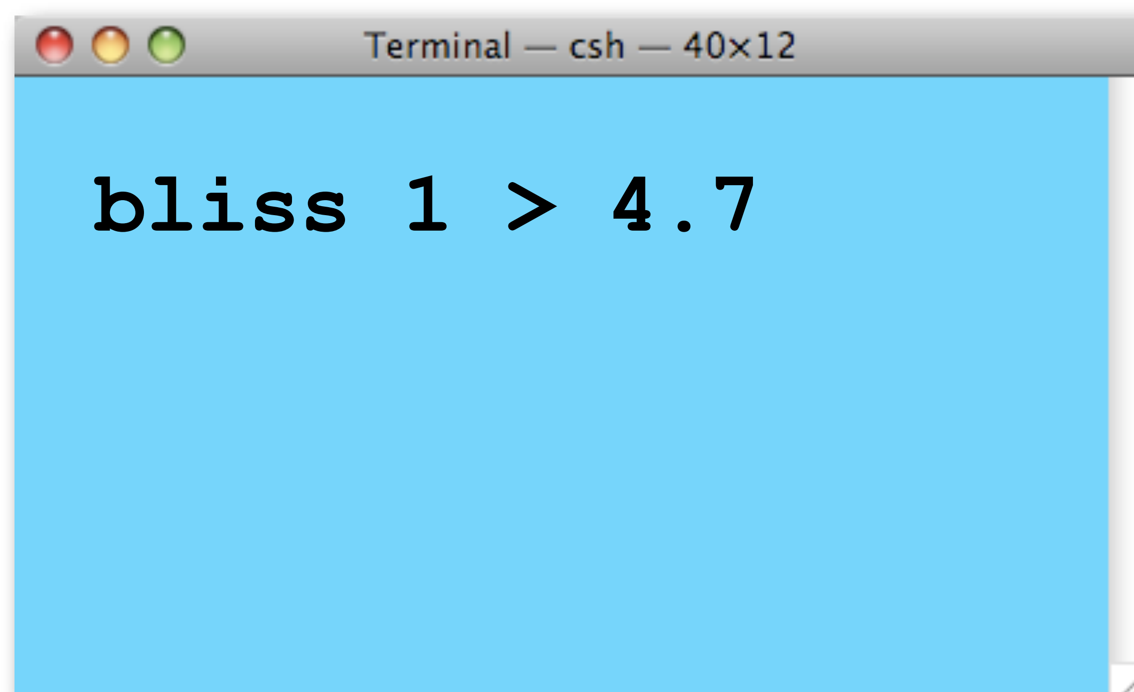

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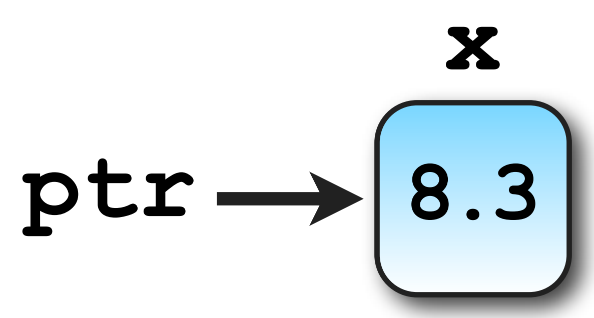

Terminal — csh — 40×12

```
bliss 1 > 4.7
bliss 2 > 8.3
```

- There are two types of pointer assignment:

  Pointer assignment **(=>)** transfers the status of one pointer to another

  Ordinary assignment **(=)** transfers values of the aliased targets in the usual way

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REAL,POINTER :: ptr1,ptr2
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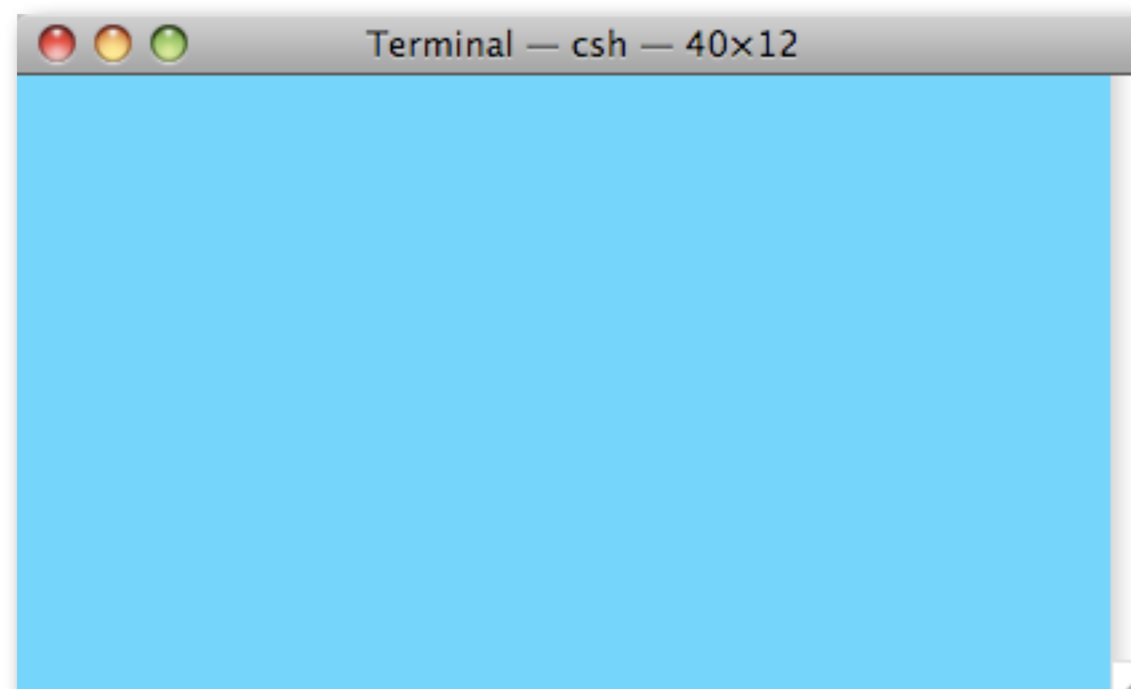

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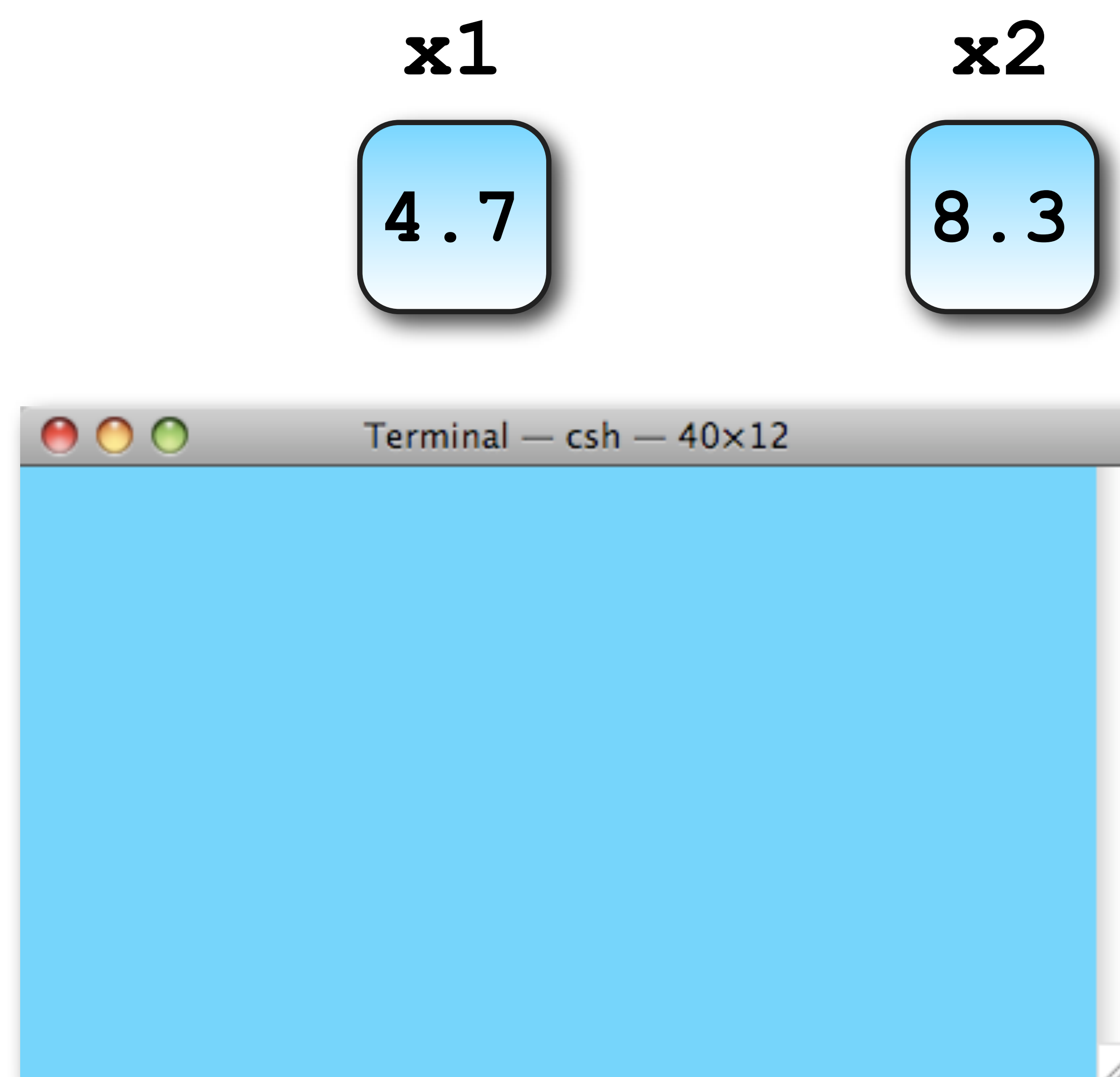

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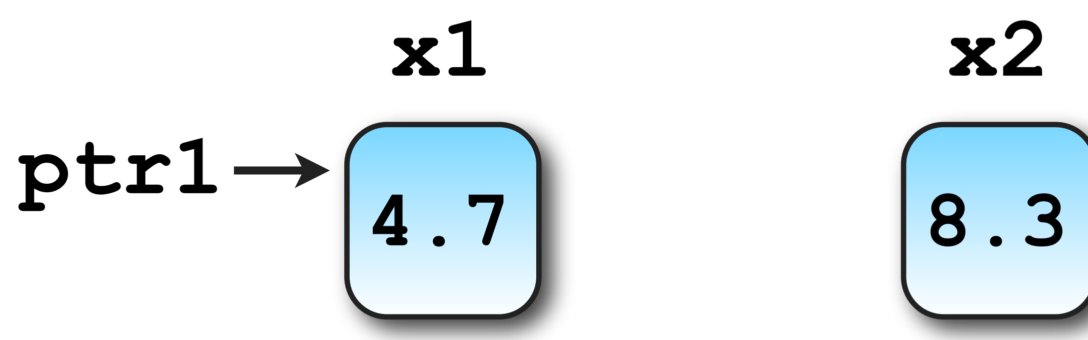

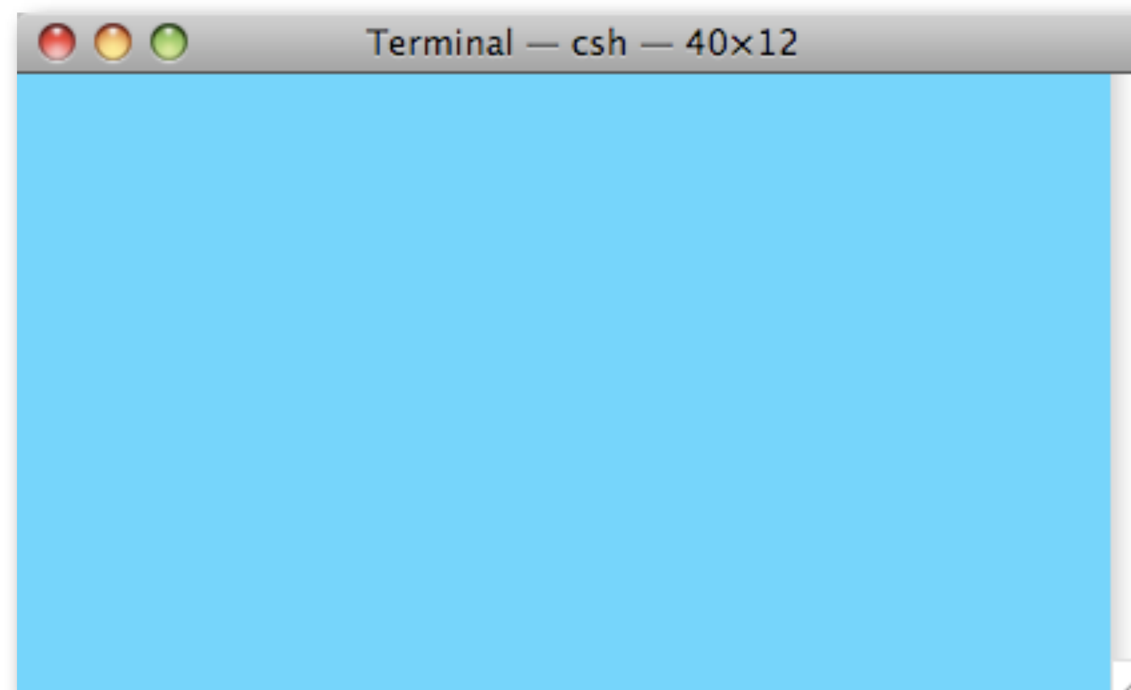

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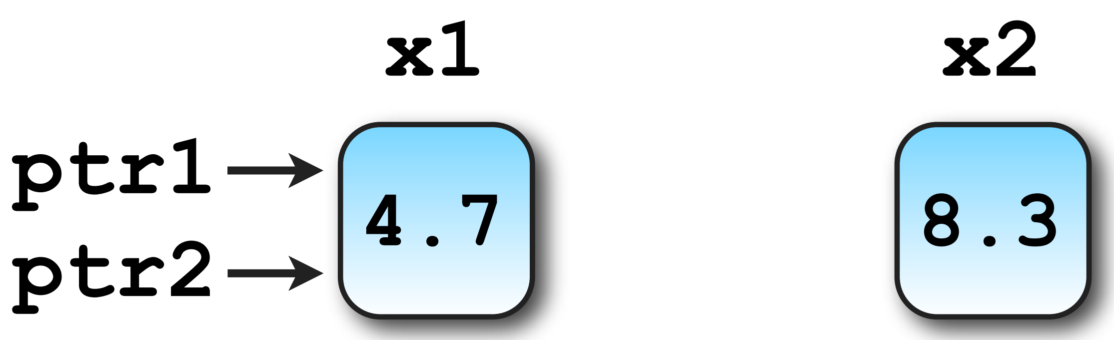

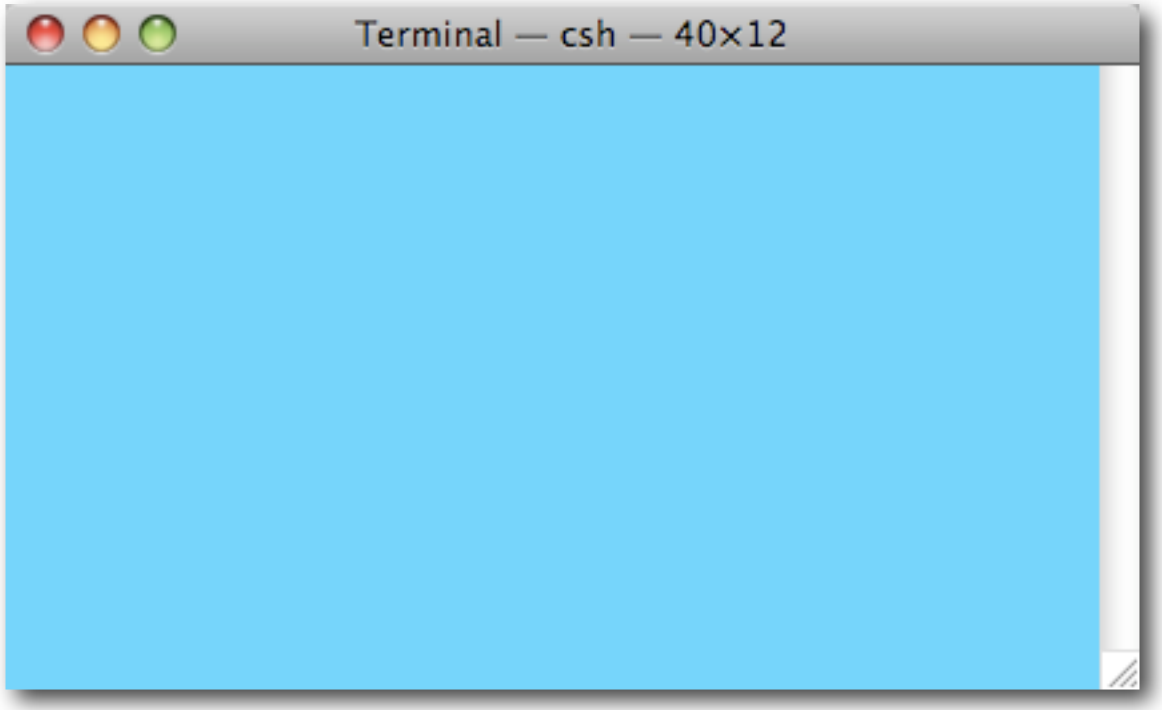

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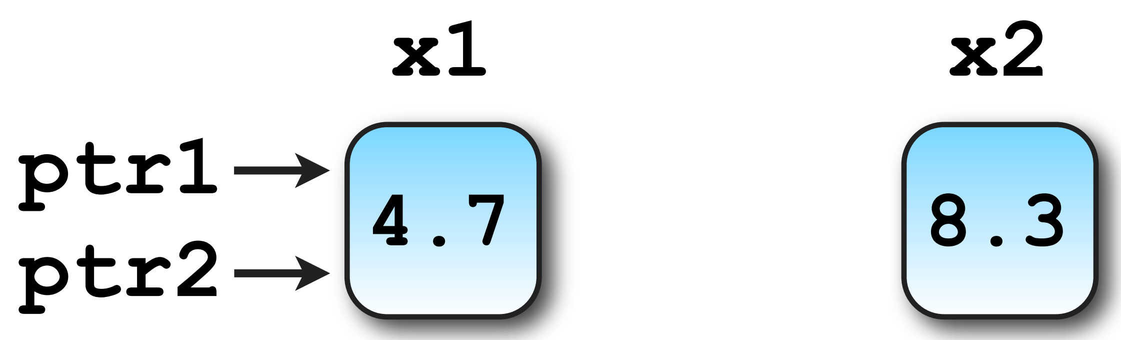

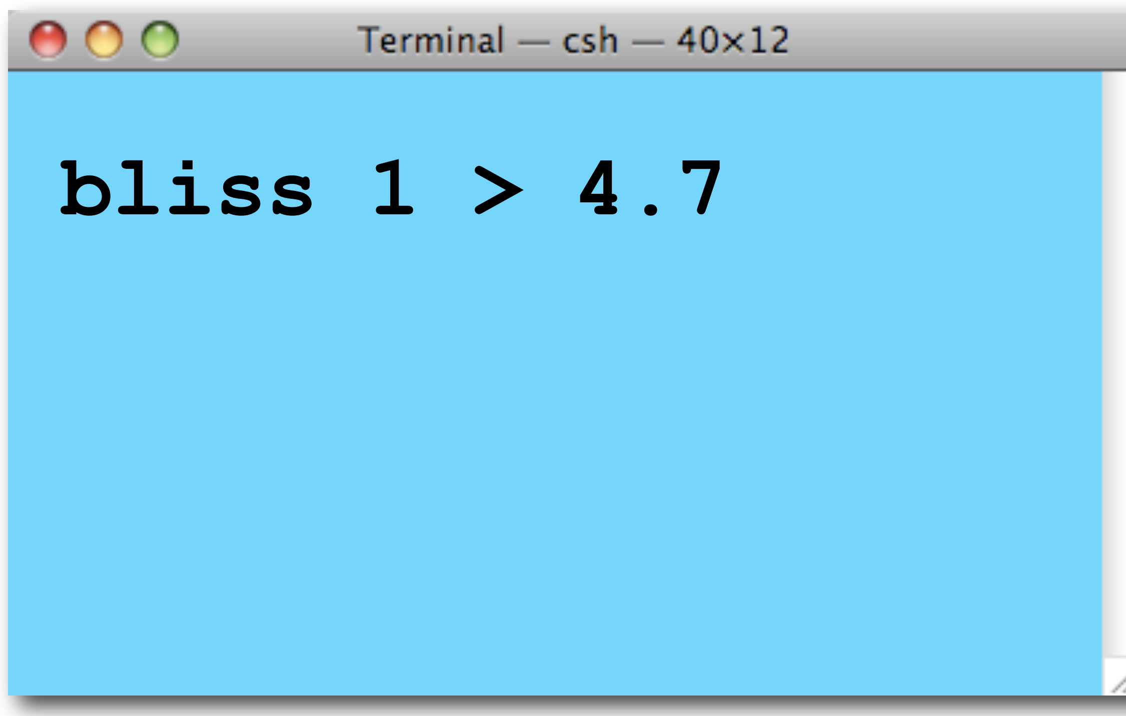

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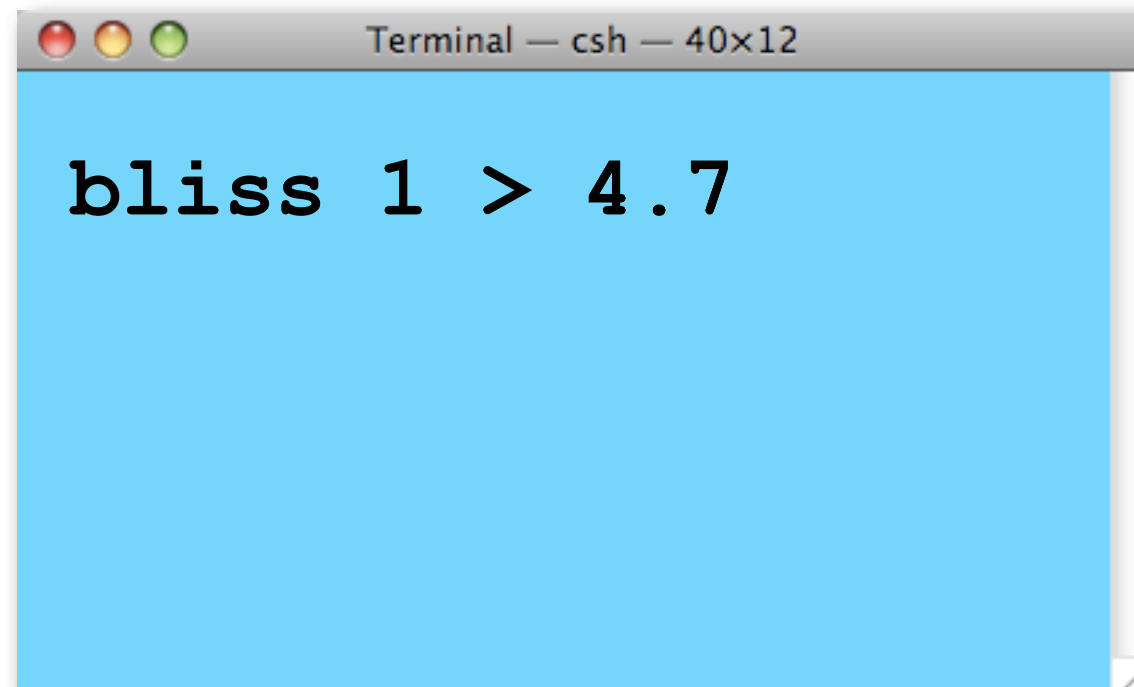

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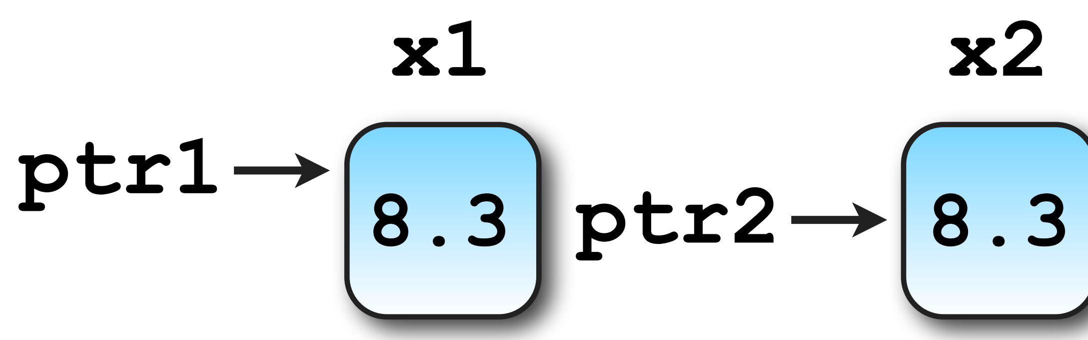

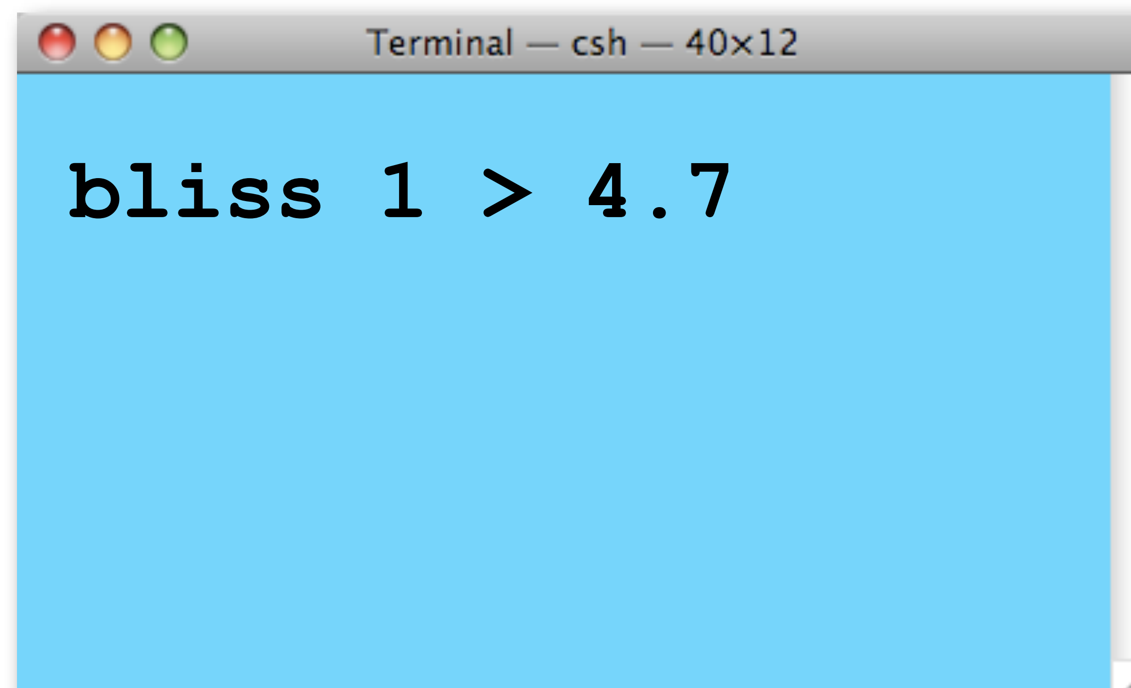

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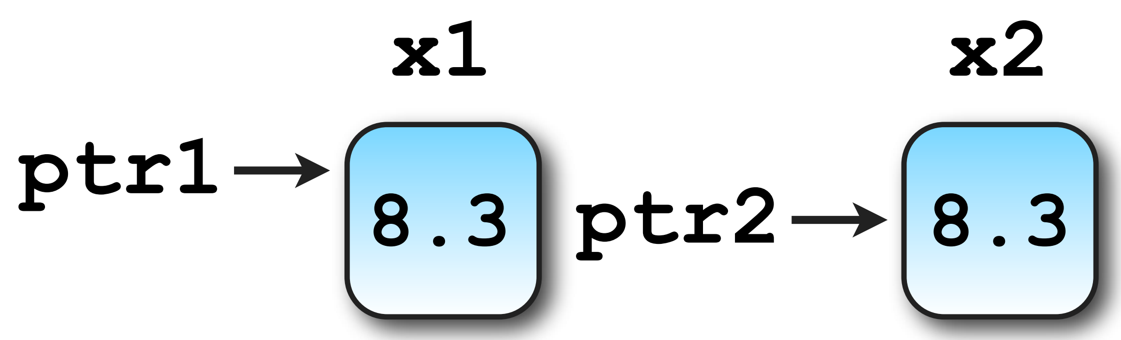

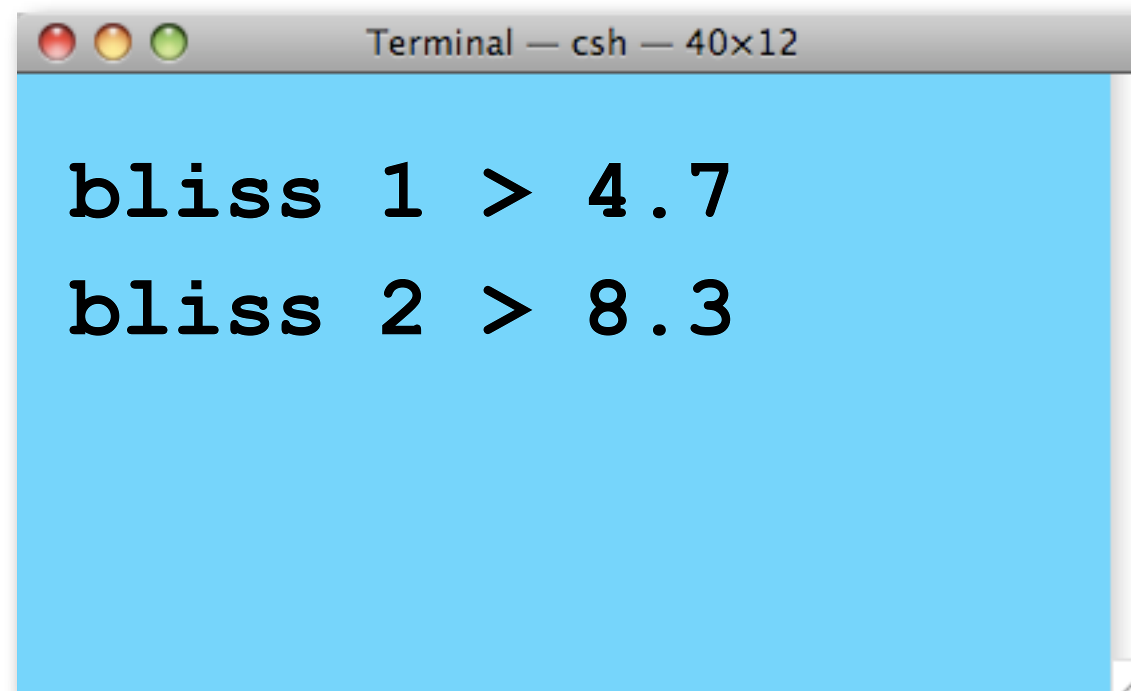

- A pointer can have three states:

  1. ***Null***. The pointer does not alias any other variable.
  2. ***Associated***. The pointer is a alias for another variable.
  3. ***Undefined***. The pointer in not null and not associated. Until a pointer is either nullified or associated it is undefined.

- The ***allocate*** statement applied to a pointer will create space and cause a pointer to refer to that space.
- The ***deallocate*** statement throws away the space pointed to by the argument and makes the argument **null**
- For example

```
REAL,POINTER :: ptr
ALLOCATE (ptr)
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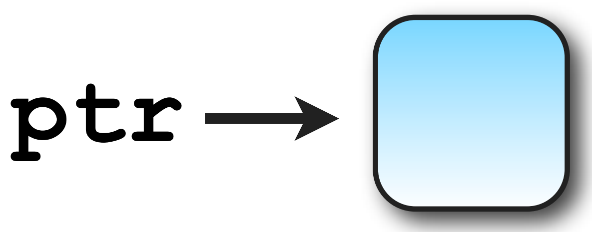

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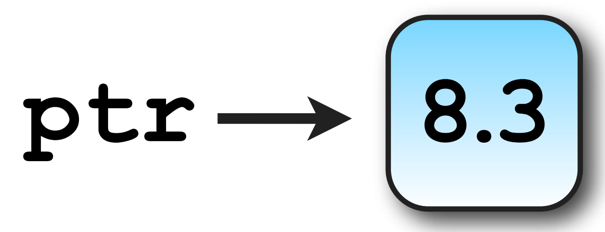

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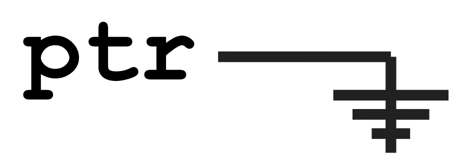

- The ***nullify*** statement causes a pointer variable to be in a state of not pointing to anything.
- Nullifying a pointer can result in unreferenced storage. That is, storage which cannot be referenced by the program.
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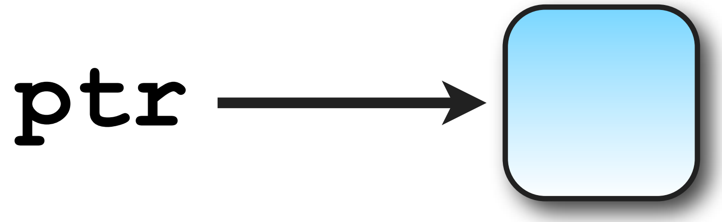

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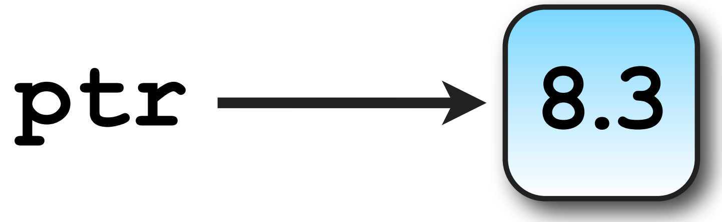


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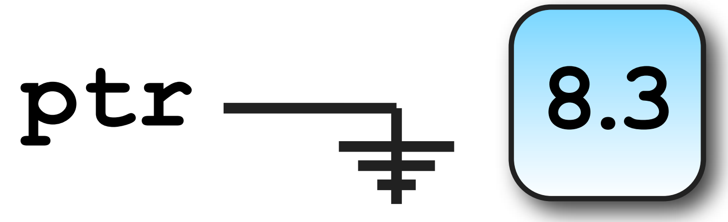
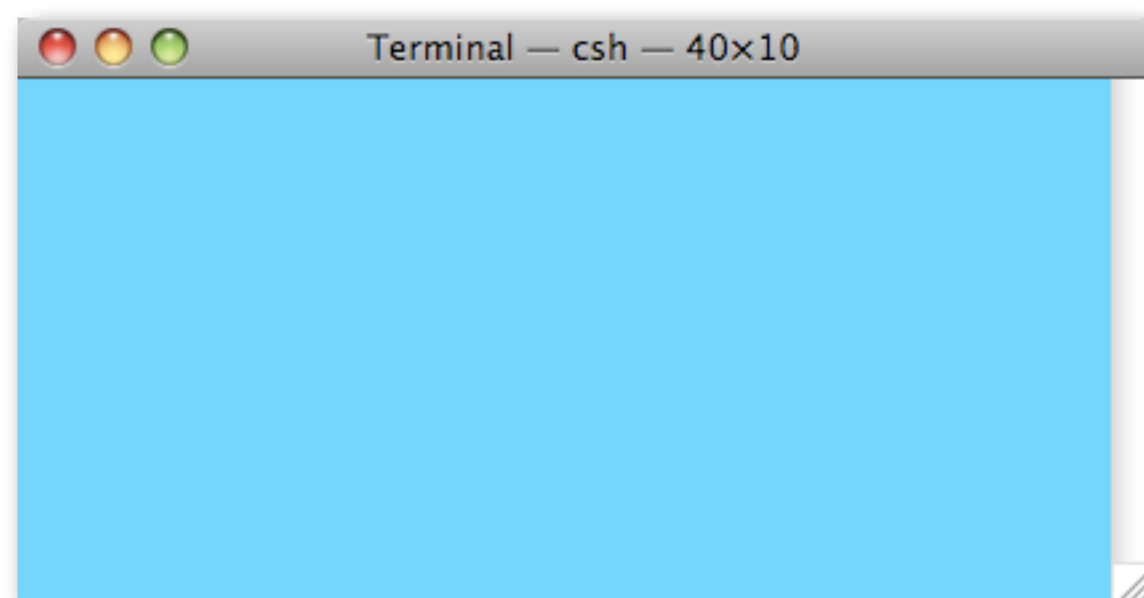


- The ***associated*** intrinsic function is used to determine if a pointer variable is pointing to another object.
- The ***associated*** intrinsic function returns true or false.
- The pointer variable must be defined. That is, it must either be null or alias some data object.
- For example


```
REAL,POINTER :: ptr
REAL,TARGET :: x

NULLIFY (ptr)
PRINT *,ASSOCIATED (ptr)
ptr => x
PRINT *,ASSOCIATED (ptr,x)
```



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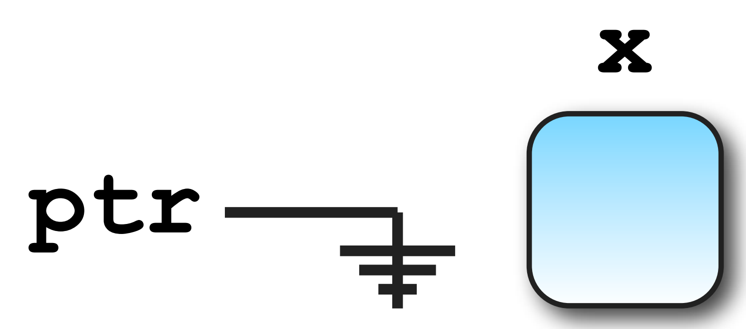


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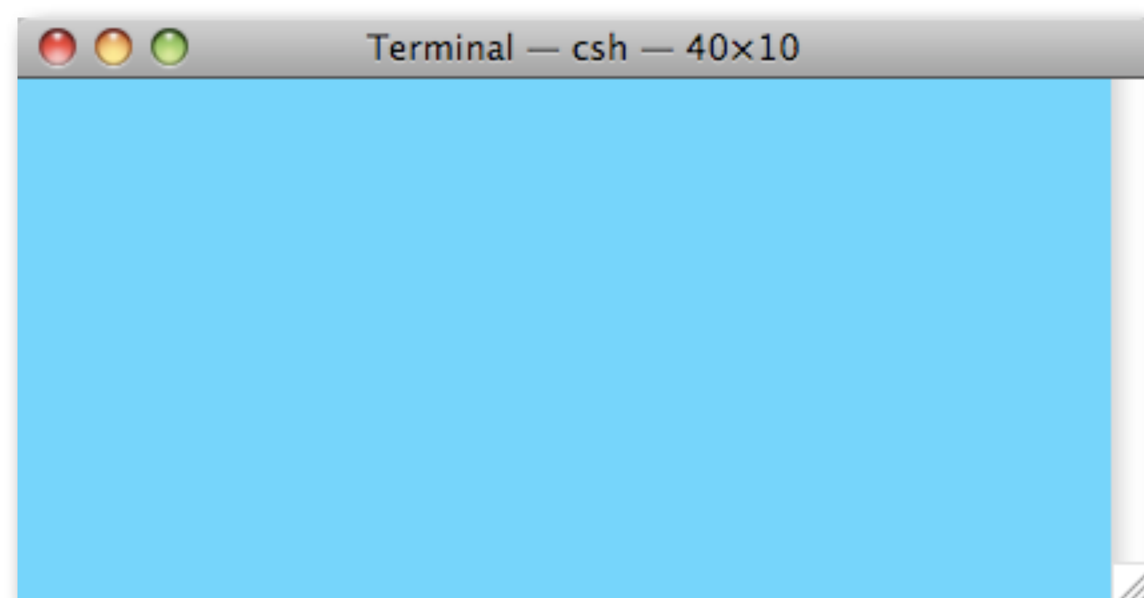

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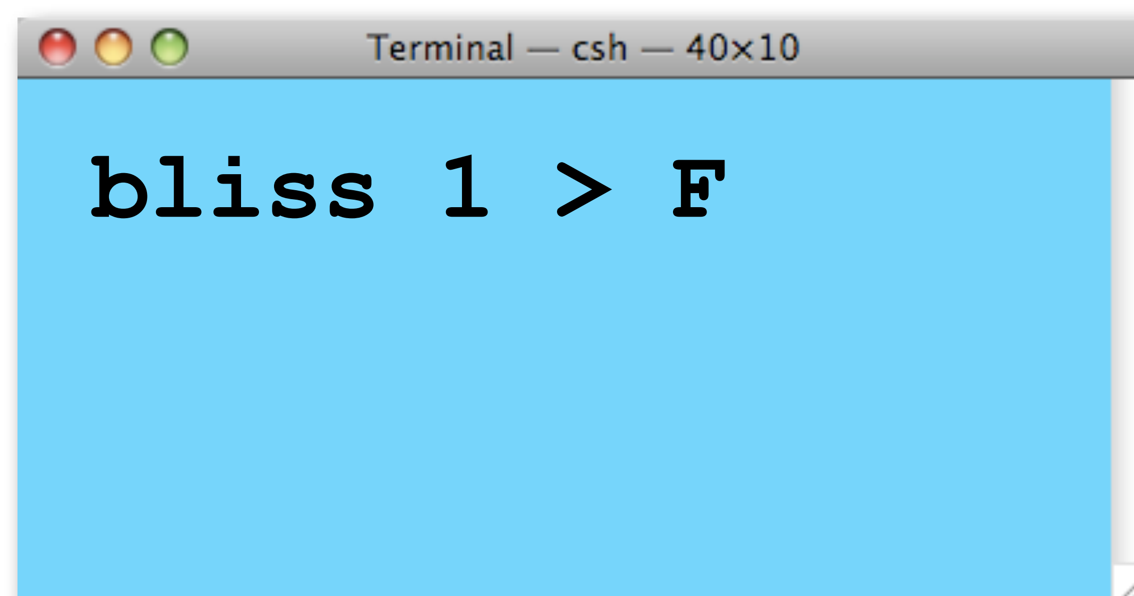

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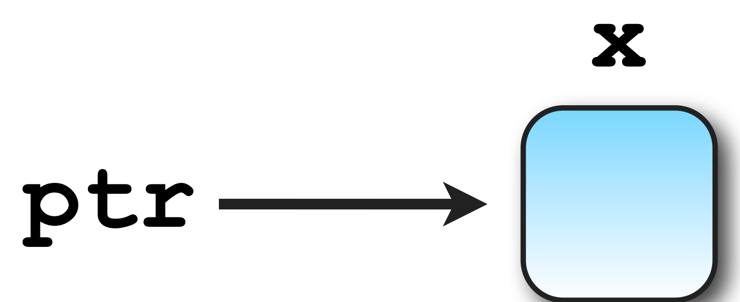


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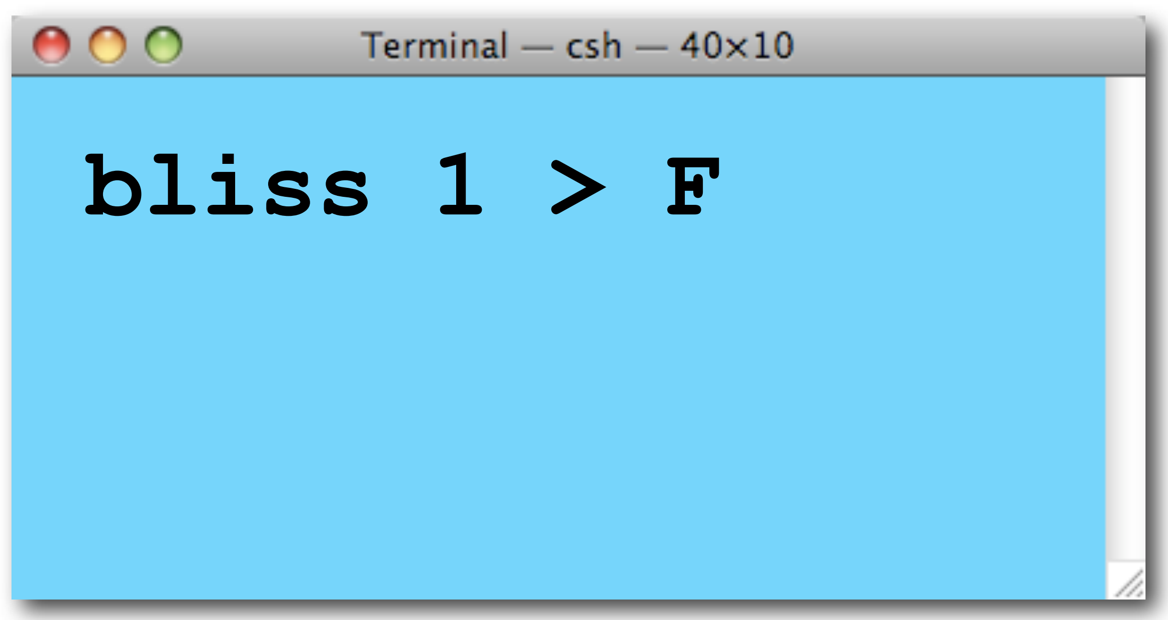

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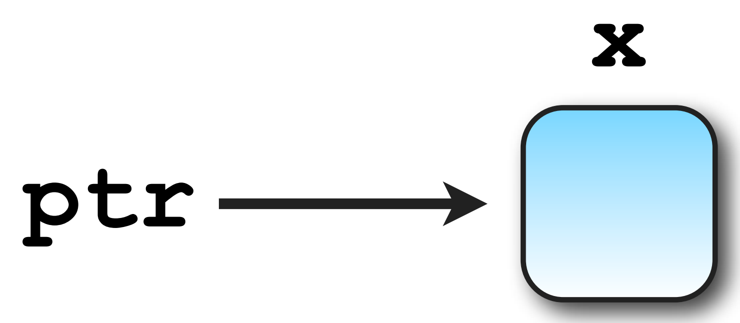


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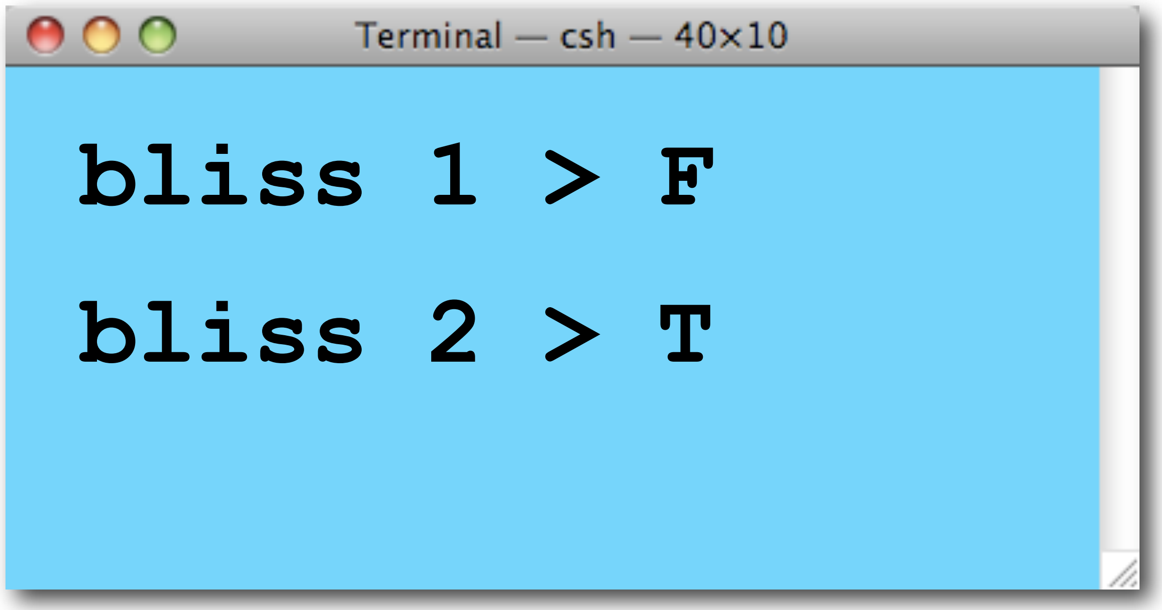

What are there good for?

- Pointers can be used to construct complicated data structures
  - Arrays of pointers
  - Linked list data structures
  - Tree data structures

Arrays of Pointers

- Suppose you have an array of things and the things are of different size
- For example, consider a *sparse matrix* where the rows have different numbers of entries.
- We can define a derived data type with a pointer as its sole component, and define arrays of this data type.
- The storage for the rows can be allocated only as necessary.
- Array assignment will copy all components.

```
TYPE row
  REAL,POINTER :: r(:)
END TYPE row

TYPE (row),POINTER :: s(n),t(n)
```

```
DO i = 1,n
  ALLOCATE (t(i)%r(1:i))
END DO
```

```
s = t
```

Linked Lists

- ***Linked lists*** are a very useful data structure when the size of the data set is not initially known. They can grow to accompany any amount of data.
- Data can be put in order "on the fly".

- A linked list is a list of ***nodes.*** Each node type contains some data and a pointer to the next node.
- The ***list*** type contains only a pointer to the first node of the list.

```
TYPE node
  INTEGER :: value
  TYPE (node),POINTER :: next
END TYPE node

TYPE list
  TYPE (node),POINTER :: first
END TYPE list
```

- Next we write the code to ***create a new linked list***

```
TYPE node
  INTEGER :: value
  TYPE (node),POINTER :: next
END TYPE node

TYPE list
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```

```
FUNCTION new_list () RESULT (lst)

  TYPE (list) :: lst

  ALLOCATE (lst%first)

  NULLIFY (lst%first%next)

END FUNCTION new_list
```

```
PROGRAM main

TYPE (list) :: lst

lst = new ()

END PROGRAM main
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- The call to function new does this:

`lst`

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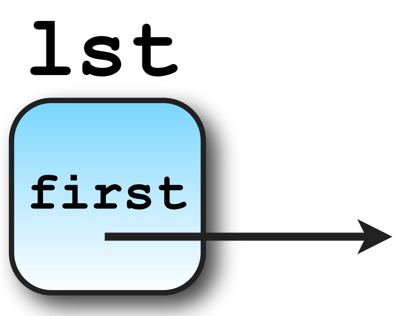

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   TYPE (node),POINTER :: next
END TYPE node

TYPE list
   TYPE (node),POINTER :: first
END TYPE list
```
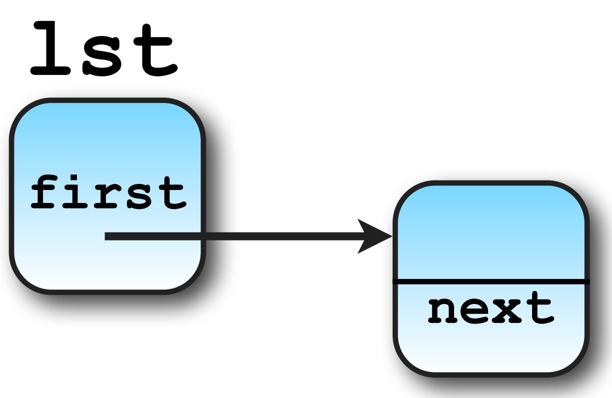

```
FUNCTION new_list () RESULT (lst)

   TYPE (list) :: lst

   ALLOCATE (lst%first)

   NULLIFY (lst%first%next)

END FUNCTION new_list
```

```
PROGRAM main

TYPE (list) :: lst

lst = new ()

END PROGRAM main
```

- The call to function new does this:



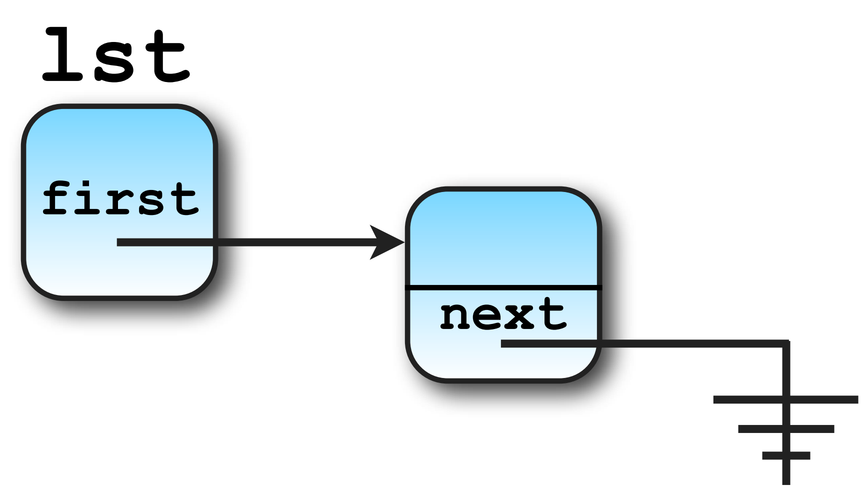
✦ Next we write the code to ***create a new linked list***

```
TYPE node
  INTEGER :: value
  TYPE (node),POINTER :: next
END TYPE node

TYPE list
  TYPE (node),POINTER :: first
END TYPE list
```

```
PROGRAM main

TYPE (list) :: lst

lst = new ()

END PROGRAM main
```

```
FUNCTION new_list () RESULT (lst)

  TYPE (list) :: lst

  ALLOCATE (lst%first)

  NULLIFY (lst%first%next)

END FUNCTION new_list
```

✦ The call to function new does this:

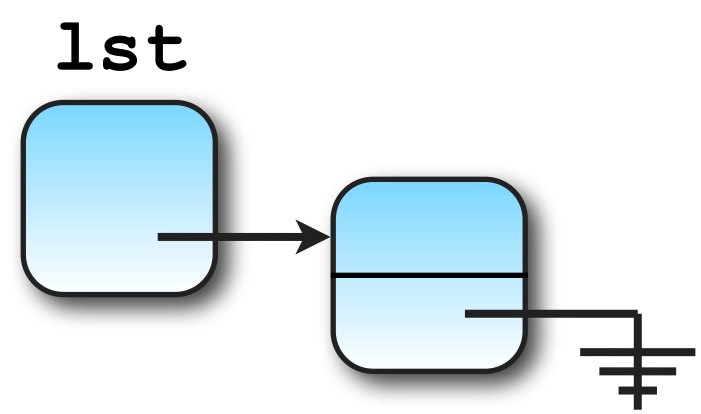


✦ Next we write the code to ***add a node*** to the linked list

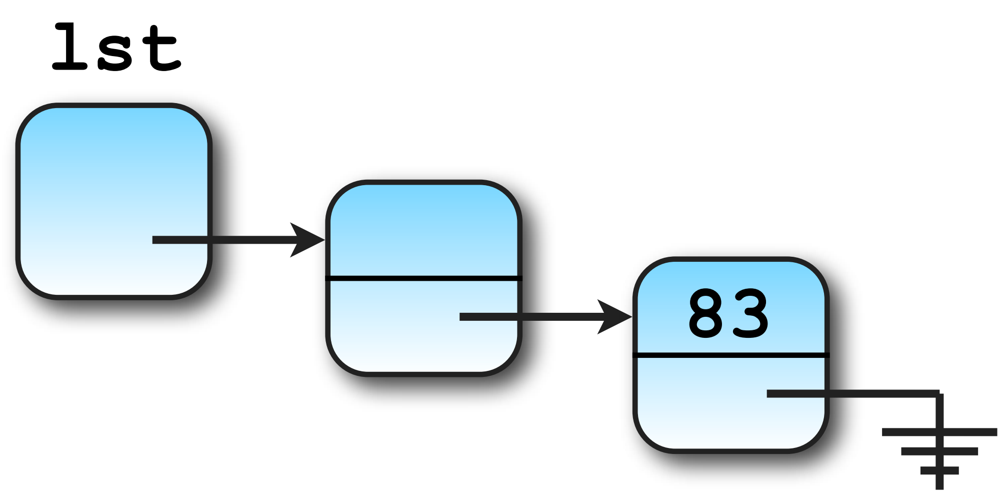
```
 SUBROUTINE insert (lst,number)
 TYPE (list) :: lst
 INTEGER :: number

 TYPE (node),POINTER :: ptr1,ptr2
! find location to put new number
 ptr1 => lst%first
 ptr2 => ptr1%next
 DO
   IF (.NOT.ASSOCIATED (ptr2)) EXIT
   IF (number < ptr2%value) EXIT
   ptr1 => ptr2
   ptr2 => ptr2%next
 ENDDO
! insert new node
 ALLOCATE (ptr1%next)
 ptr1%next%value = number
 ptr1%next%next => ptr2

 END SUBROUTINE insert
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)

END PROGRAM main
```

✦ The first call to insert does this:



✦ The second call to insert does this:

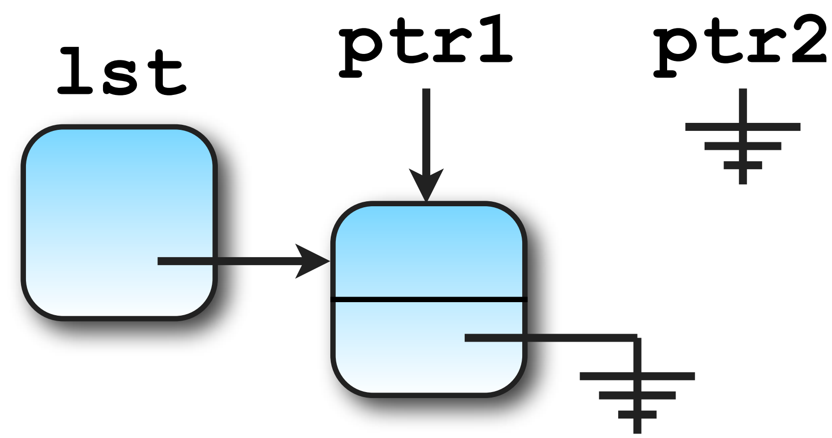


✦ Next we write the code to ***add a node*** to the linked list

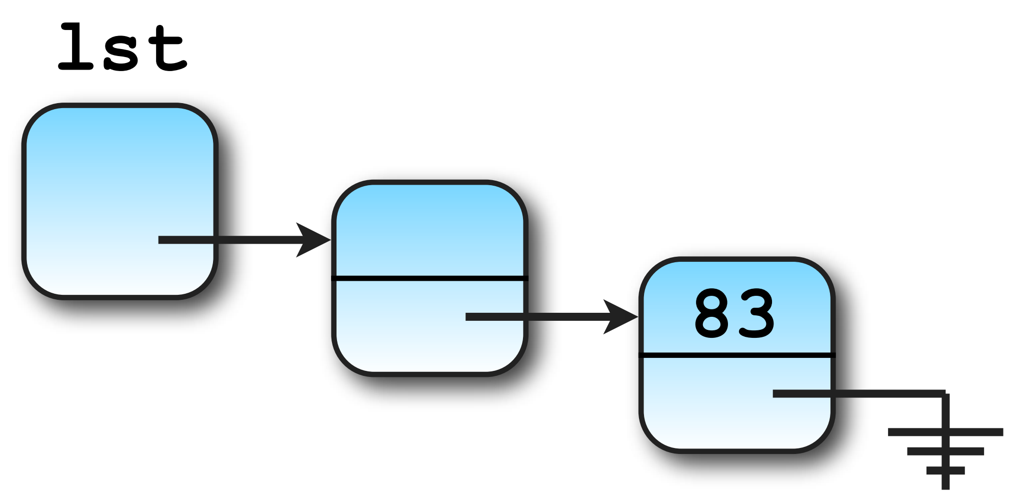
```
 SUBROUTINE insert (lst,number)
 TYPE (list) :: lst
 INTEGER :: number

 TYPE (node),POINTER :: ptr1,ptr2
! find location to put new number
 ptr1 => lst%first
 ptr2 => ptr1%next
 DO
   IF (.NOT.ASSOCIATED (ptr2)) EXIT
   IF (number < ptr2%value) EXIT
   ptr1 => ptr2
   ptr2 => ptr2%next
 ENDDO
! insert new node
 ALLOCATE (ptr1%next)
 ptr1%next%value = number
 ptr1%next%next => ptr2

 END SUBROUTINE insert
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)

END PROGRAM main
```

- The first call to insert does this:



- The second call to insert does this:

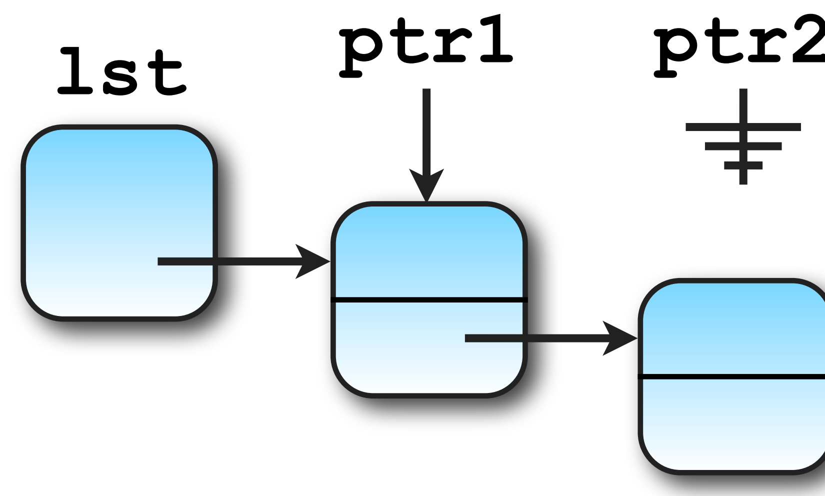


✦ Next we write the code to ***add a node*** to the linked list

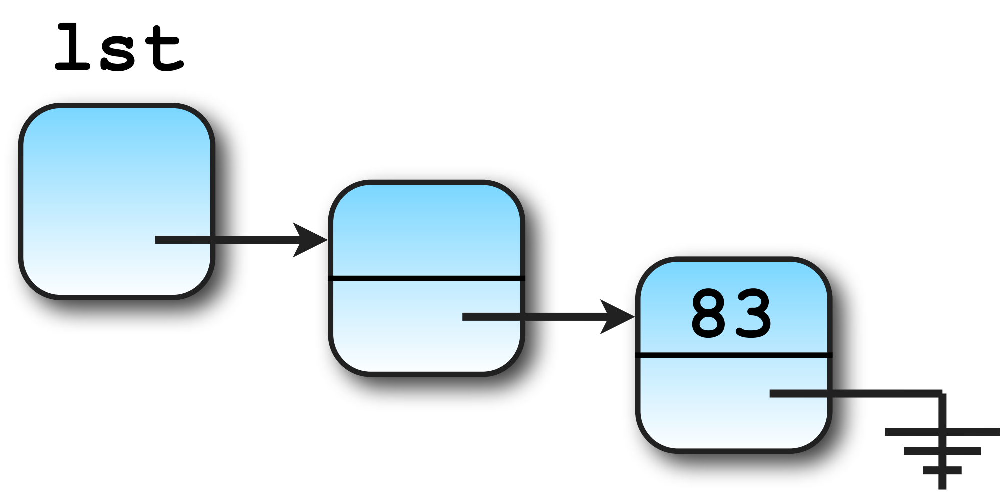
```
 SUBROUTINE insert (lst,number)
 TYPE (list) :: lst
 INTEGER :: number

 TYPE (node),POINTER :: ptr1,ptr2
! find location to put new number
 ptr1 => lst%first
 ptr2 => ptr1%next
 DO
   IF (.NOT.ASSOCIATED (ptr2)) EXIT
   IF (number < ptr2%value) EXIT
   ptr1 => ptr2
   ptr2 => ptr2%next
 ENDDO
! insert new node
 ALLOCATE (ptr1%next)
 ptr1%next%value = number
 ptr1%next%next => ptr2

 END SUBROUTINE insert
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)

END PROGRAM main
```

✦ The first call to insert does this:



✦ The second call to insert does this:

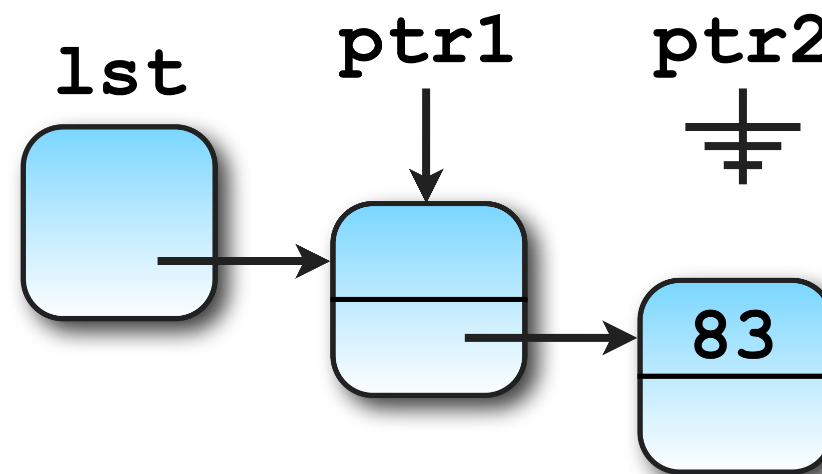


✦ Next we write the code to ***add a node*** to the linked list

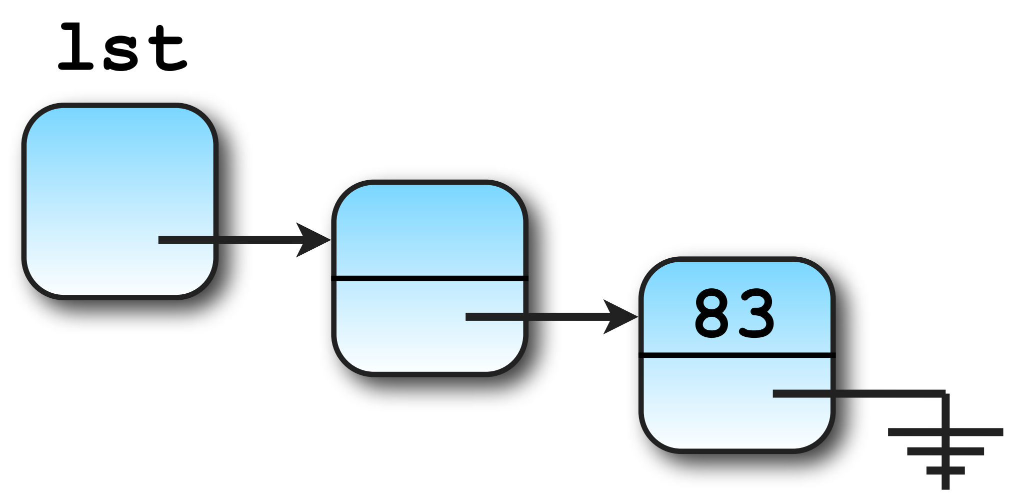
```
 SUBROUTINE insert (lst,number)
 TYPE (list) :: lst
 INTEGER :: number

 TYPE (node),POINTER :: ptr1,ptr2
! find location to put new number
 ptr1 => lst%first
 ptr2 => ptr1%next
 DO
   IF (.NOT.ASSOCIATED (ptr2)) EXIT
   IF (number < ptr2%value) EXIT
   ptr1 => ptr2
   ptr2 => ptr2%next
 ENDDO
! insert new node
 ALLOCATE (ptr1%next)
 ptr1%next%value = number
 ptr1%next%next => ptr2

 END SUBROUTINE insert
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)

END PROGRAM main
```

✦ The first call to insert does this:



✦ The second call to insert does this:



✦ Next we write the code to ***add a node*** to the linked list

```
 SUBROUTINE insert (lst,number)
 TYPE (list) :: lst
 INTEGER :: number

 TYPE (node),POINTER :: ptr1,ptr2
! find location to put new number
 ptr1 => lst%first
 ptr2 => ptr1%next
 DO
   IF (.NOT.ASSOCIATED (ptr2)) EXIT
   IF (number < ptr2%value) EXIT
   ptr1 => ptr2
   ptr2 => ptr2%next
 ENDDO
! insert new node
 ALLOCATE (ptr1%next)
 ptr1%next%value = number
 ptr1%next%next => ptr2

 END SUBROUTINE insert
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)

END PROGRAM main
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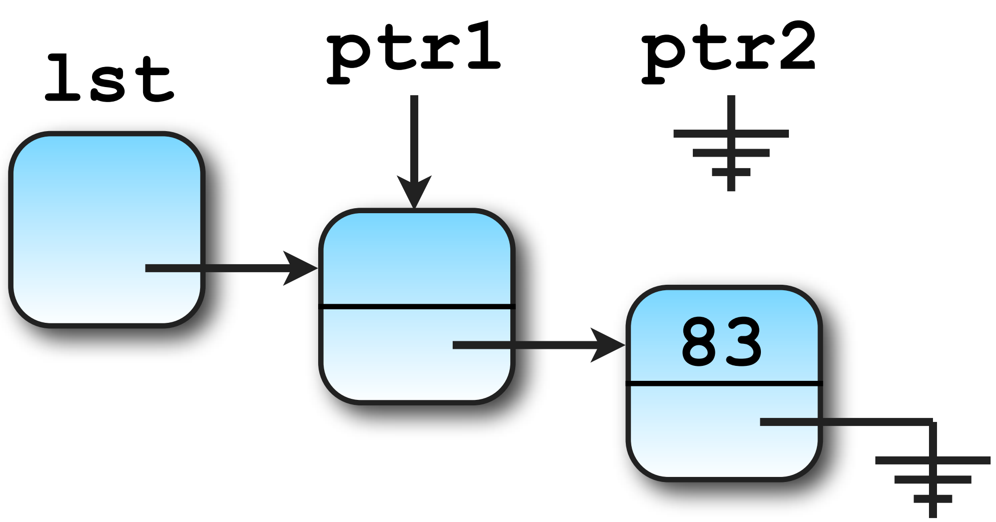
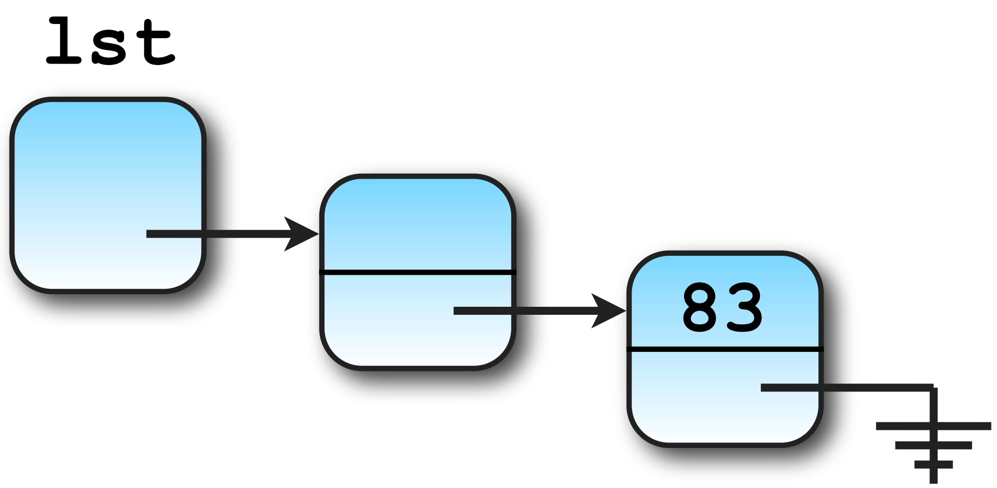
✦ The first call to insert does this:



✦ The second call to insert does this:



✦ Next we write the code to ***add a node*** to the linked list

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SUBROUTINE insert (lst,number)
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INTEGER :: number

TYPE (node),POINTER :: ptr1,ptr2
! find location to put new number
ptr1 => lst%first
ptr2 => ptr1%next
DO
  IF (.NOT.ASSOCIATED (ptr2)) EXIT
  IF (number < ptr2%value) EXIT
  ptr1 => ptr2
  ptr2 => ptr2%next
ENDDO
! insert new node
ALLOCATE (ptr1%next)
ptr1%next%value = number
ptr1%next%next => ptr2

END SUBROUTINE insert
```
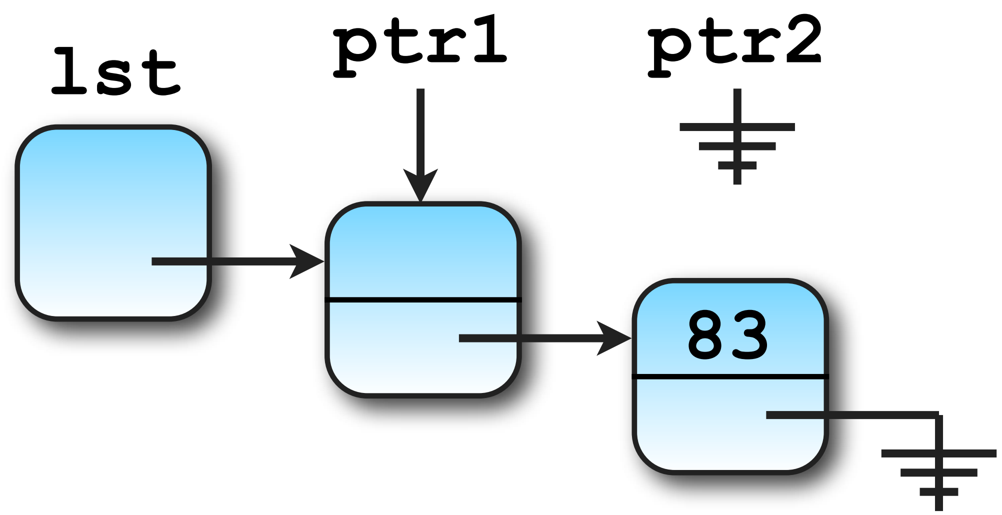
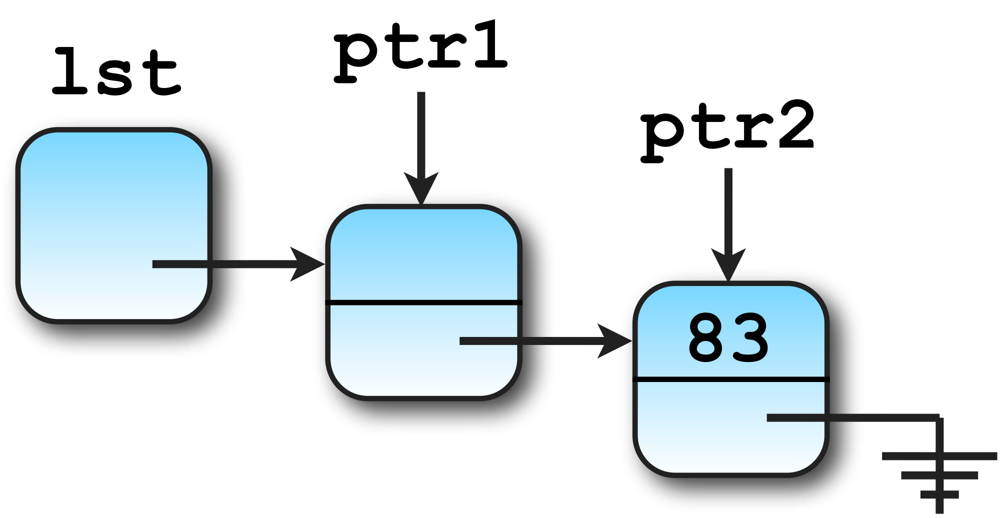

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)

END PROGRAM main
```

- ✦ The first call to insert does this:



- ✦ The second call to insert does this:

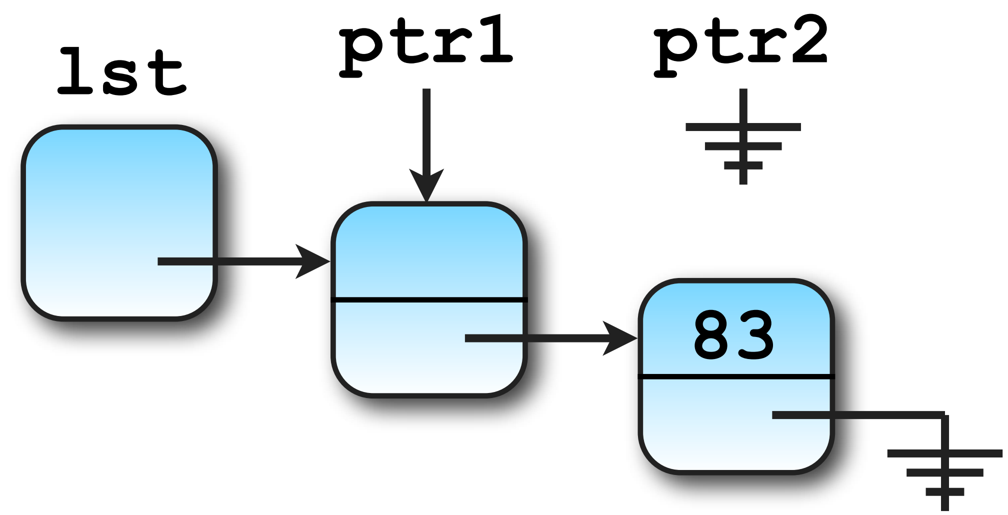


✦ Next we write the code to ***add a node*** to the linked list

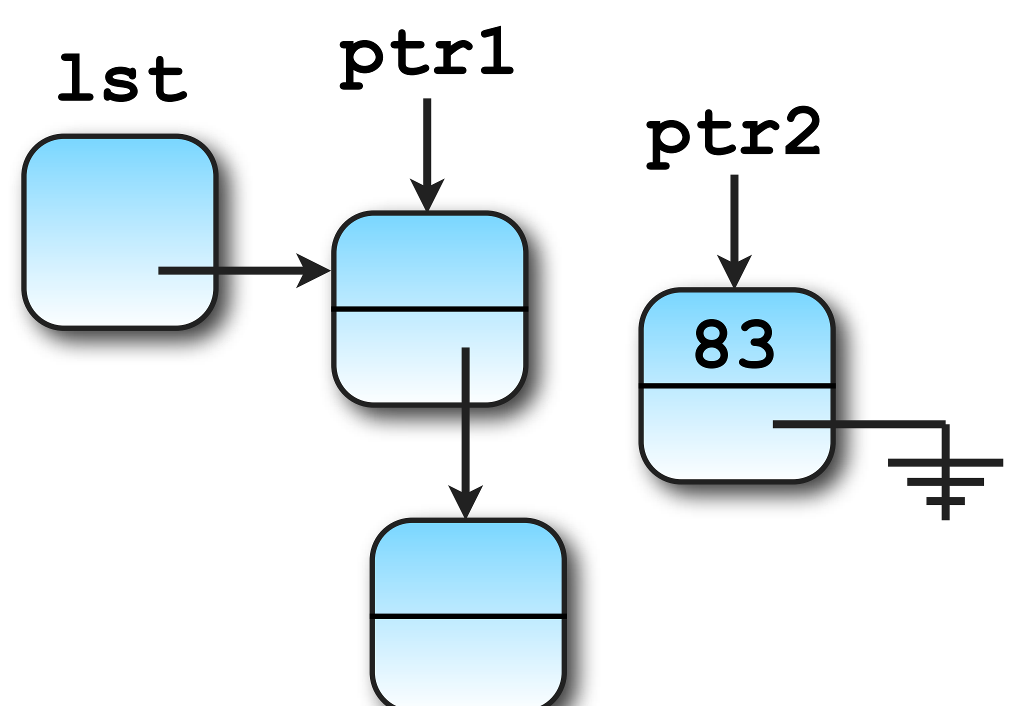
```
 SUBROUTINE insert (lst,number)
 TYPE (list) :: lst
 INTEGER :: number

 TYPE (node),POINTER :: ptr1,ptr2
! find location to put new number
 ptr1 => lst%first
 ptr2 => ptr1%next
 DO
   IF (.NOT.ASSOCIATED (ptr2)) EXIT
   IF (number < ptr2%value) EXIT
   ptr1 => ptr2
   ptr2 => ptr2%next
 ENDDO
! insert new node
 ALLOCATE (ptr1%next)
 ptr1%next%value = number
 ptr1%next%next => ptr2

 END SUBROUTINE insert
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)

END PROGRAM main
```

✦ The first call to insert does this:



✦ The second call to insert does this:

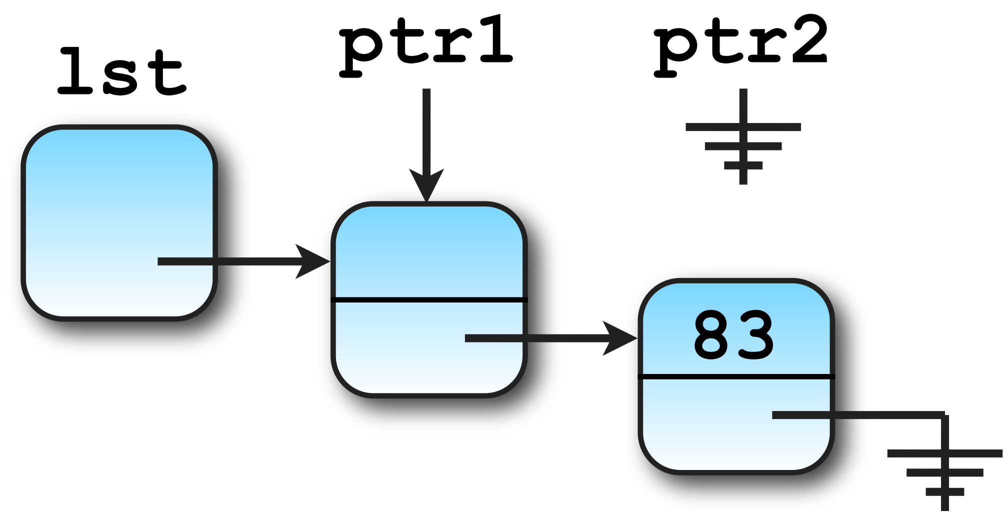


✦ Next we write the code to ***add a node*** to the linked list

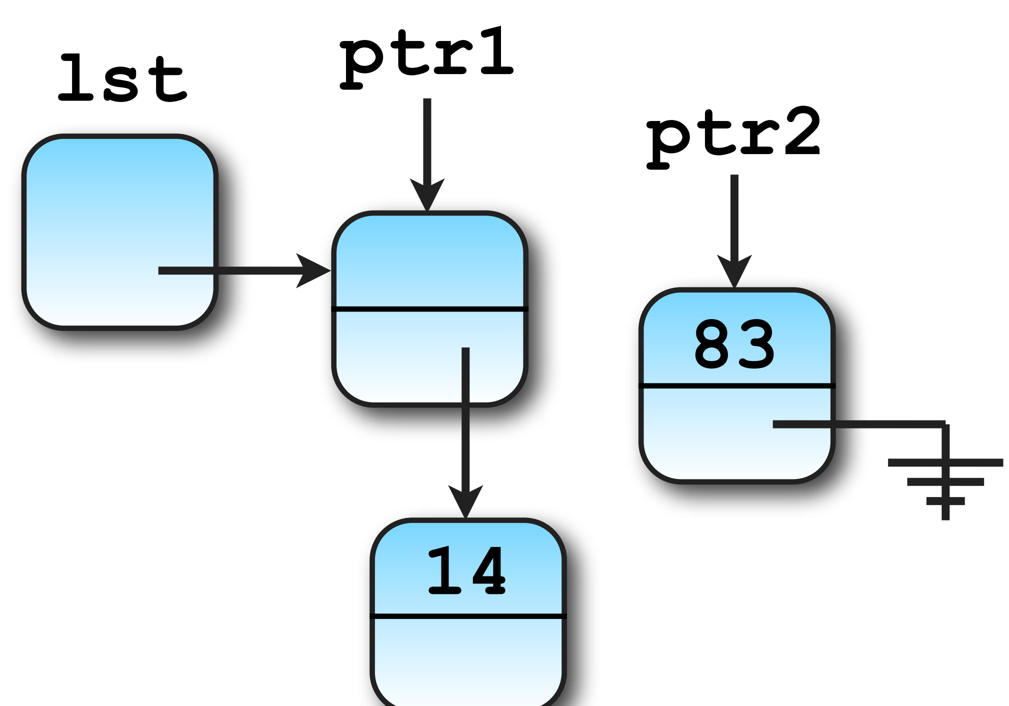
```
 SUBROUTINE insert (lst,number)
 TYPE (list) :: lst
 INTEGER :: number

 TYPE (node),POINTER :: ptr1,ptr2
! find location to put new number
 ptr1 => lst%first
 ptr2 => ptr1%next
 DO
   IF (.NOT.ASSOCIATED (ptr2)) EXIT
   IF (number < ptr2%value) EXIT
   ptr1 => ptr2
   ptr2 => ptr2%next
 ENDDO
! insert new node
 ALLOCATE (ptr1%next)
 ptr1%next%value = number
 ptr1%next%next => ptr2

 END SUBROUTINE insert
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)

END PROGRAM main
```

- The first call to insert does this:



- The second call to insert does this:

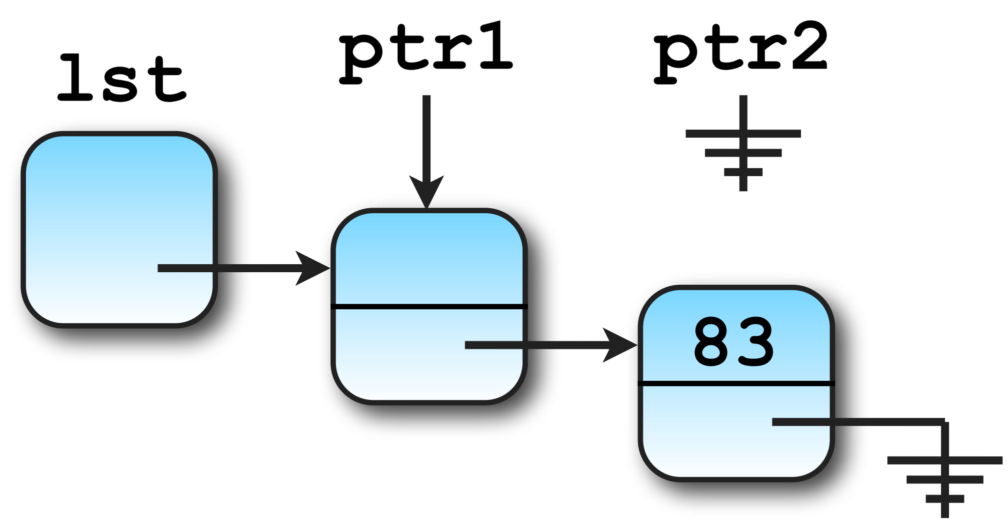


✦ Next we write the code to ***add a node*** to the linked list

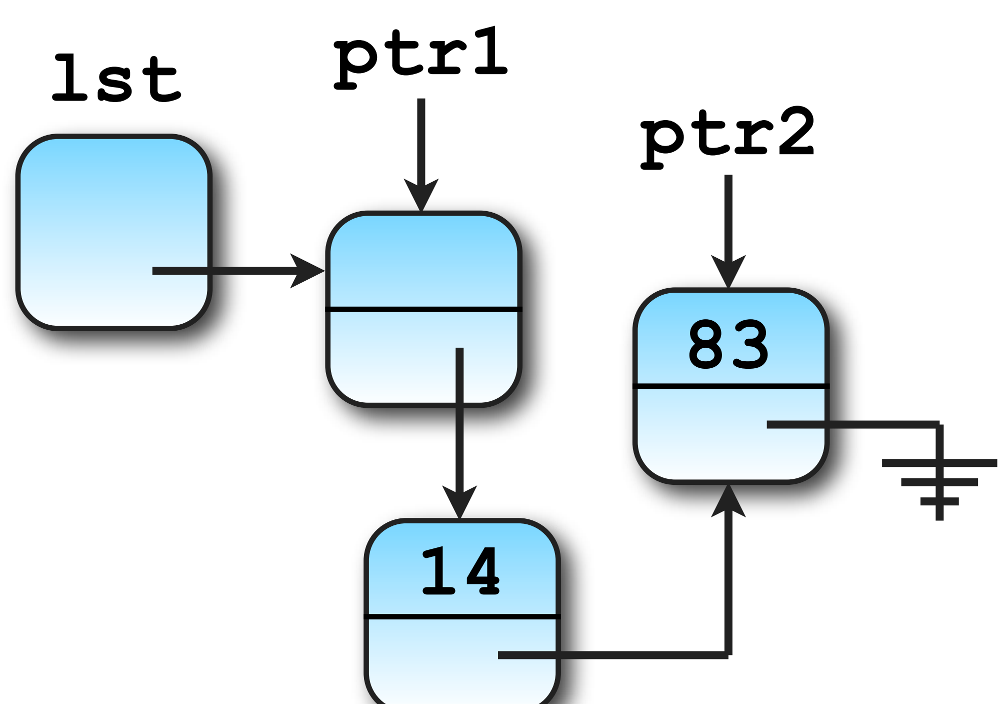
```
SUBROUTINE insert (lst,number)
TYPE (list) :: lst
INTEGER :: number

TYPE (node),POINTER :: ptr1,ptr2
! find location to put new number
ptr1 => lst%first
ptr2 => ptr1%next
DO
  IF (.NOT.ASSOCIATED (ptr2)) EXIT
  IF (number < ptr2%value) EXIT
  ptr1 => ptr2
  ptr2 => ptr2%next
ENDDO
! insert new node
ALLOCATE (ptr1%next)
ptr1%next%value = number
ptr1%next%next => ptr2

END SUBROUTINE insert
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)

END PROGRAM main
```

✦ The first call to insert does this:



✦ The second call to insert does this:

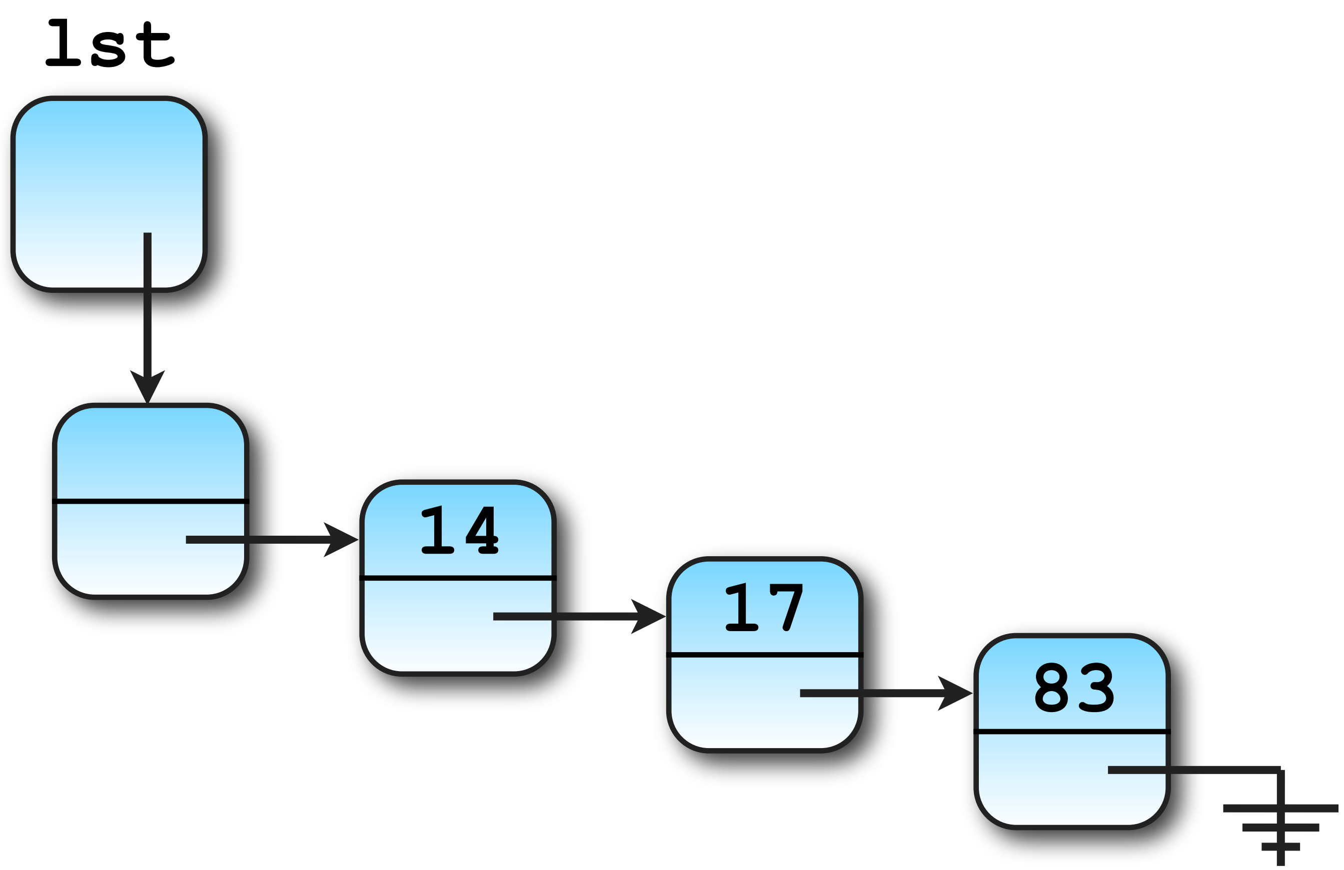


✦ Next we write the code to ***delete a node*** from the list

```
SUBROUTINE delete (lst,number)
TYPE (list) :: lst
INTEGER :: number

LOGICAL :: found
TYPE (node),POINTER :: ptr1,ptr2
! find location to delete number
ptr1 => lst%first
ptr2 => ptr1%next
DO
  IF (.NOT.ASSOCIATED (ptr2)) THEN
    found = .FALSE.
    EXIT
  ELSE IF (number==ptr2%value) THEN
    found = .TRUE.
    EXIT
  ELSE
    ptr1 => ptr2
    ptr2 => ptr2%next
  ENDIF
ENDDO
! delete node if found
IF (found) THEN
  ptr1%next => ptr2%next
  DEALLOCATE (ptr2)
ENDIF

END SUBROUTINE delete
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)
CALL insert (lst,17)

CALL delete (lst,17)

END PROGRAM main
```

✦ The call to delete does this:

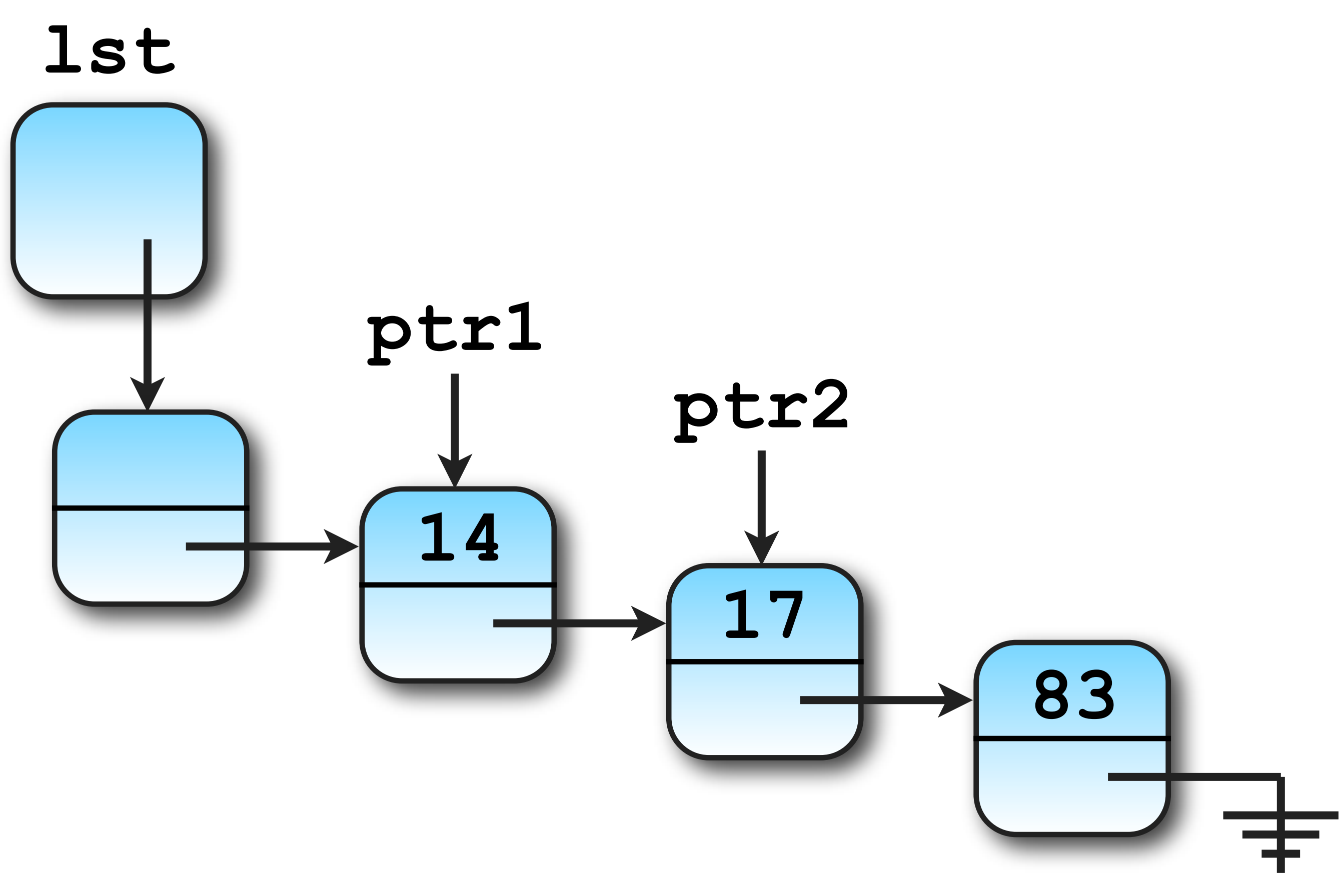


✦ Next we write the code to ***delete a node*** from the list

```
 SUBROUTINE delete (lst,number)
 TYPE (list) :: lst
 INTEGER :: number

 LOGICAL :: found
 TYPE (node),POINTER :: ptr1,ptr2
! find location to delete number
 ptr1 => lst%first
 ptr2 => ptr1%next
 DO
   IF (.NOT.ASSOCIATED (ptr2)) THEN
     found = .FALSE.
     EXIT
   ELSE IF (number==ptr2%value) THEN
     found = .TRUE.
     EXIT
   ELSE
     ptr1 => ptr2
     ptr2 => ptr2%next
   ENDIF
 ENDDO
! delete node if found
 IF (found) THEN
   ptr1%next => ptr2%next
   DEALLOCATE (ptr2)
 ENDIF

 END SUBROUTINE delete
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)
CALL insert (lst,17)

CALL delete (lst,17)

END PROGRAM main
```

✦ The call to delete does this:

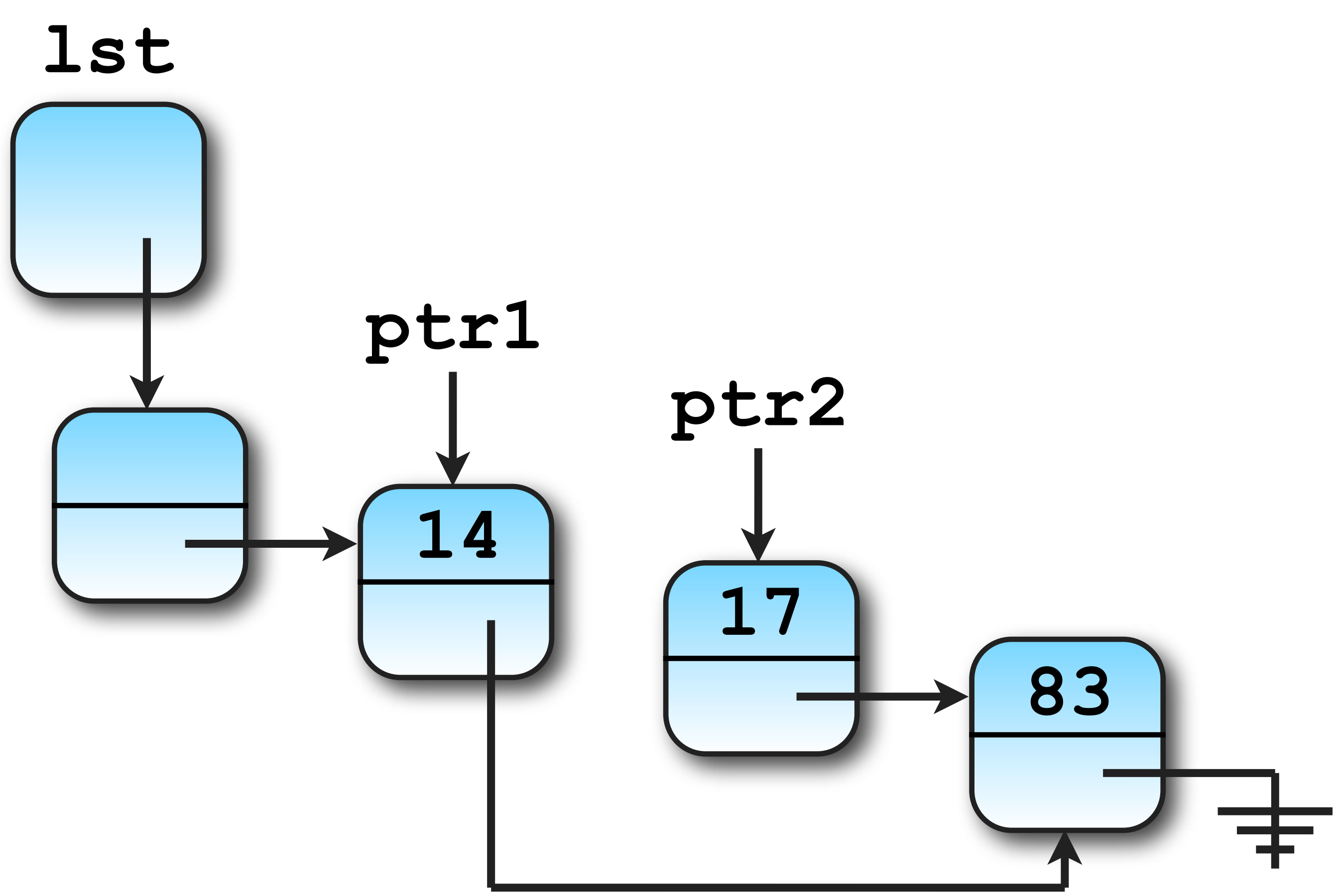


✦ Next we write the code to ***delete a node*** from the list

```
SUBROUTINE delete (lst,number)
TYPE (list) :: lst
INTEGER :: number

LOGICAL :: found
TYPE (node),POINTER :: ptr1,ptr2
! find location to delete number
ptr1 => lst%first
ptr2 => ptr1%next
DO
  IF (.NOT.ASSOCIATED (ptr2)) THEN
    found = .FALSE.
    EXIT
  ELSE IF (number==ptr2%value) THEN
    found = .TRUE.
    EXIT
  ELSE
    ptr1 => ptr2
    ptr2 => ptr2%next
  ENDIF
ENDDO
! delete node if found
IF (found) THEN
  ptr1%next => ptr2%next
  DEALLOCATE (ptr2)
ENDIF

END SUBROUTINE delete
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)
CALL insert (lst,17)

CALL delete (lst,17)

END PROGRAM main
```

✦ The call to delete does this:

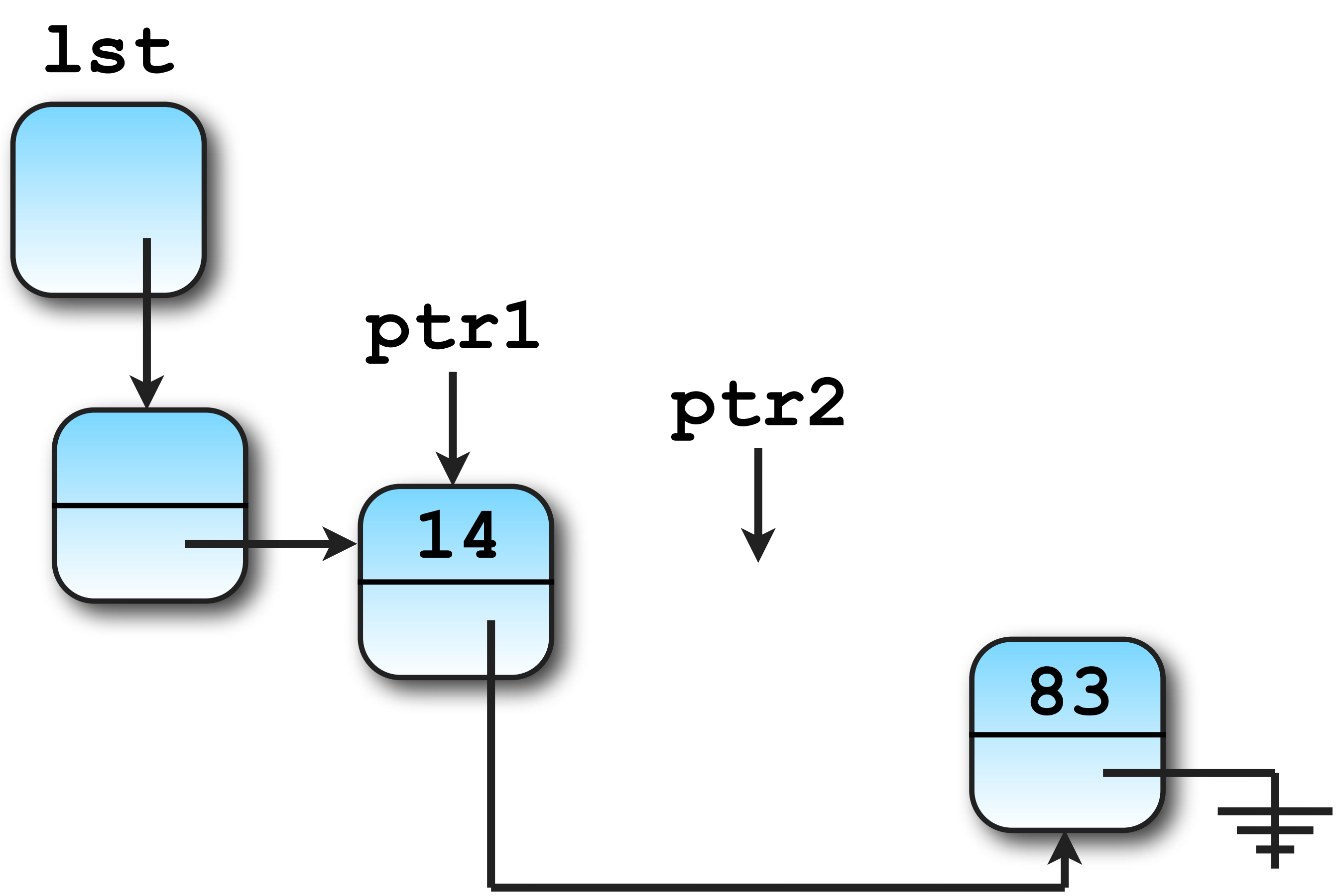


✦ Next we write the code to ***delete a node*** from the list

```
SUBROUTINE delete (lst,number)
TYPE (list) :: lst
INTEGER :: number

LOGICAL :: found
TYPE (node),POINTER :: ptr1,ptr2
! find location to delete number
ptr1 => lst%first
ptr2 => ptr1%next
DO
  IF (.NOT.ASSOCIATED (ptr2)) THEN
    found = .FALSE.
    EXIT
  ELSE IF (number==ptr2%value) THEN
    found = .TRUE.
    EXIT
  ELSE
    ptr1 => ptr2
    ptr2 => ptr2%next
  ENDIF
ENDDO
! delete node if found
IF (found) THEN
  ptr1%next => ptr2%next
  DEALLOCATE (ptr2)
ENDIF

END SUBROUTINE delete
```

```
PROGRAM main

lst = new ()
CALL insert (lst,83)
CALL insert (lst,14)
CALL insert (lst,17)

CALL delete (lst,17)

END PROGRAM main
```

✦ The call to delete does this:



✦ Next we write the code to ***print*** the linked list

```
SUBROUTINE print_list (lst)

TYPE (list) :: lst
TYPE (node),POINTER :: ptr

ptr => lst%first%next

DO
  IF (.NOT.ASSOCIATED (ptr)) EXIT
    PRINT *,ptr%value
    ptr => ptr%next
  ENDIF
ENDDO

END SUBROUTINE print_list
```

Binary Trees

- Storing data is linked list requires n^2 operations where n is the number of pieces of data.
- Storing data in the binary tree only requires $n \log_2 n$ operations.

✦ Next we write the code to ***create a new binary tree***

```
TYPE node
  INTEGER :: value
  TYPE (node),POINTER :: left,right
END TYPE node
TYPE (node),POINTER :: tree
```

```
RECURSIVE SUBROUTINE insert (tree,number)
TYPE (node) :: tree
INTEGER :: number

IF (.NOT.ASSOCIATED (tree)) THEN
  ALLOCATE (tree)
  tree%value = number
  NULLIFY (tree%left)
  NULLIFY (tree%right)
ELSE IF (number < tree%value) THEN
  CALL insert (tree%left,number)
ELSE
  CALL insert (tree%right,number)
ENDIF

END SUBROUTINE insert
```

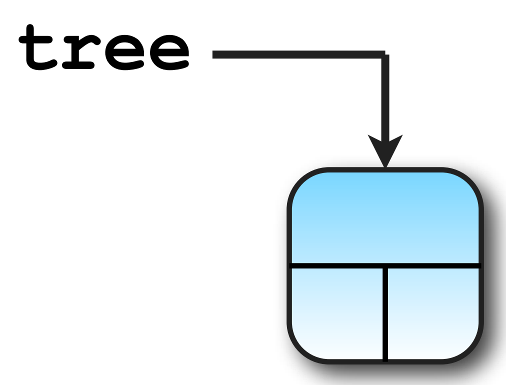
```
PROGRAM main

NULLIFY (tree)
CALL insert (tree,83)
CALL insert (tree,14)
CALL insert (tree,17)
CALL insert (tree,91)
CALL insert (tree,11)

END PROGRAM main
```

✦ Next we write the code to ***create a new binary tree***

```
TYPE node
  INTEGER :: value
  TYPE (node),POINTER :: left,right
END TYPE node
TYPE (node),POINTER :: tree
```

```
RECURSIVE SUBROUTINE insert (tree,number)
TYPE (node) :: tree
INTEGER :: number

IF (.NOT.ASSOCIATED (tree)) THEN
  ALLOCATE (tree)
  tree%value = number
  NULLIFY (tree%left)
  NULLIFY (tree%right)
ELSE IF (number < tree%value) THEN
  CALL insert (tree%left,number)
ELSE
  CALL insert (tree%right,number)
ENDIF

END SUBROUTINE insert
```

```
PROGRAM main

NULLIFY (tree)
CALL insert (tree,83)
CALL insert (tree,14)
CALL insert (tree,17)
CALL insert (tree,91)
CALL insert (tree,11)

END PROGRAM main
```

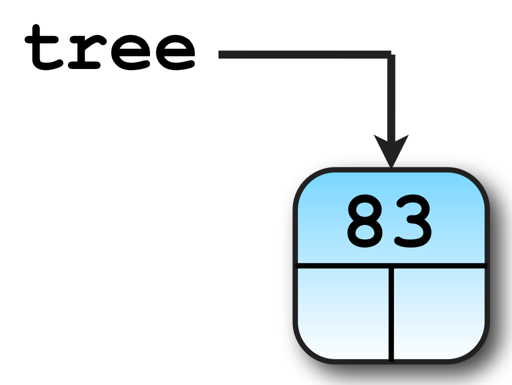


✦ Next we write the code to ***create a new binary tree***

```
TYPE node
  INTEGER :: value
  TYPE (node),POINTER :: left,right
END TYPE node
TYPE (node),POINTER :: tree
```

```
RECURSIVE SUBROUTINE insert (tree,number)
TYPE (node) :: tree
INTEGER :: number

IF (.NOT.ASSOCIATED (tree)) THEN
  ALLOCATE (tree)
  tree%value = number
  NULLIFY (tree%left)
  NULLIFY (tree%right)
ELSE IF (number < tree%value) THEN
  CALL insert (tree%left,number)
ELSE
  CALL insert (tree%right,number)
ENDIF

END SUBROUTINE insert
```

```
PROGRAM main

NULLIFY (tree)
CALL insert (tree,83)
CALL insert (tree,14)
CALL insert (tree,17)
CALL insert (tree,91)
CALL insert (tree,11)

END PROGRAM main
```

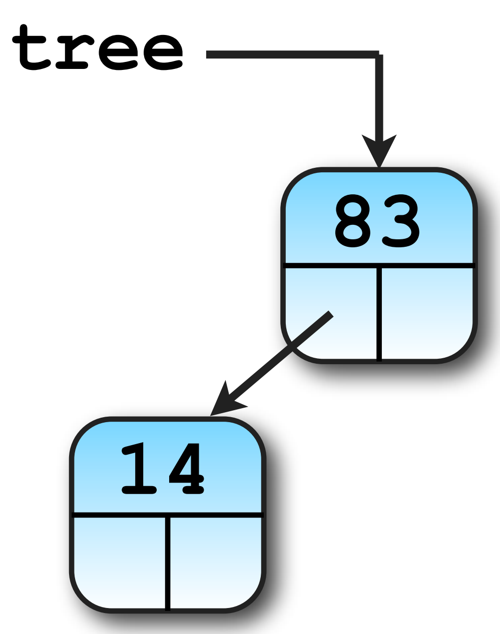


✦ Next we write the code to ***create a new binary tree***

```
TYPE node
  INTEGER :: value
  TYPE (node),POINTER :: left,right
END TYPE node
TYPE (node),POINTER :: tree
```

```
RECURSIVE SUBROUTINE insert (tree,number)
TYPE (node) :: tree
INTEGER :: number

IF (.NOT.ASSOCIATED (tree)) THEN
  ALLOCATE (tree)
  tree%value = number
  NULLIFY (tree%left)
  NULLIFY (tree%right)
ELSE IF (number < tree%value) THEN
  CALL insert (tree%left,number)
ELSE
  CALL insert (tree%right,number)
ENDIF

END SUBROUTINE insert
```

```
PROGRAM main

NULLIFY (tree)
CALL insert (tree,83)
CALL insert (tree,14)
CALL insert (tree,17)
CALL insert (tree,91)
CALL insert (tree,11)

END PROGRAM main
```

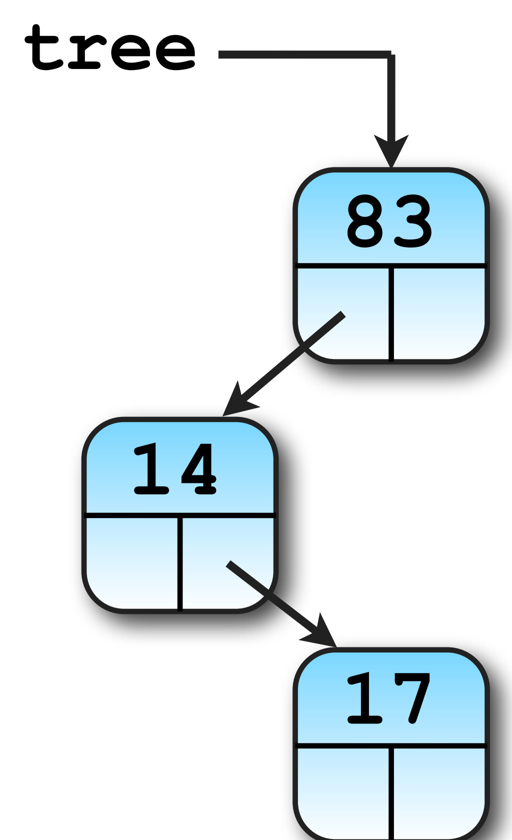


✦ Next we write the code to ***create a new binary tree***

```
TYPE node
  INTEGER :: value
  TYPE (node),POINTER :: left,right
END TYPE node
TYPE (node),POINTER :: tree
```

```
RECURSIVE SUBROUTINE insert (tree,number)
TYPE (node) :: tree
INTEGER :: number

IF (.NOT.ASSOCIATED (tree)) THEN
  ALLOCATE (tree)
  tree%value = number
  NULLIFY (tree%left)
  NULLIFY (tree%right)
ELSE IF (number < tree%value) THEN
  CALL insert (tree%left,number)
ELSE
  CALL insert (tree%right,number)
ENDIF

END SUBROUTINE insert
```

```
PROGRAM main

NULLIFY (tree)
CALL insert (tree,83)
CALL insert (tree,14)
CALL insert (tree,17)
CALL insert (tree,91)
CALL insert (tree,11)

END PROGRAM main
```



✦ Next we write the code to ***create a new binary tree***

```
TYPE node
  INTEGER :: value
  TYPE (node),POINTER :: left,right
END TYPE node
TYPE (node),POINTER :: tree
```

```
RECURSIVE SUBROUTINE insert (tree,number)
TYPE (node) :: tree
INTEGER :: number

IF (.NOT.ASSOCIATED (tree)) THEN
  ALLOCATE (tree)
  tree%value = number
  NULLIFY (tree%left)
  NULLIFY (tree%right)
ELSE IF (number < tree%value) THEN
  CALL insert (tree%left,number)
ELSE
  CALL insert (tree%right,number)
ENDIF

END SUBROUTINE insert
```

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CALL insert (tree,14)
CALL insert (tree,17)
CALL insert (tree,91)
CALL insert (tree,11)

END PROGRAM main
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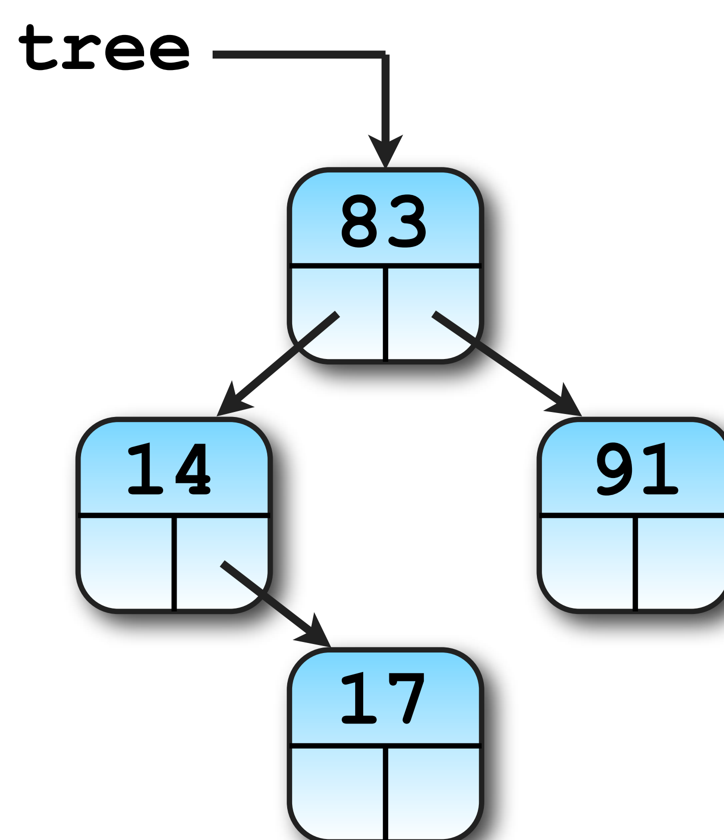

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END SUBROUTINE insert
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