CSE 340 FALL 2021

Pointer Semantics Step by Step Example

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We will examine a complicated C program and analyze the pointer operations

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At each step, we will draw the box-circle diagrams to illustrate the effects of the operations

We start with the declarations section of the program

```
#include <stdio.h>
#include <stdlib.h>

struct T {
    int a;
    int *b;
    struct T *next;
};

struct T p0;

struct T *p1;
struct T **p2;

int *p;
int *q;
```

```
#include <stdio.h> // standard input/output
#include <stdlib.h> // standard library
                     // structure T
struct T {
                    // integer field
      int a;
                     // pointer to int
      int *b;
      struct T *next; // pointer to struct T
} ;
                      // p0's type is struct T
struct T p0;
                      // (not pointer)
struct T *p1;
struct T **p2;
int *p;
int *q;
```

```
#include <stdio.h> // standard input/output
#include <stdlib.h> // standard library
                     // structure T
struct T {
                    // integer field
      int a;
                     // pointer to int
      int *b;
      struct T *next; // pointer to struct T
} ;
                      // p0's type is struct T
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                      // (not pointer)
                      // pointer to struct T
struct T *p1;
struct T **p2;
int *p;
int *q;
```

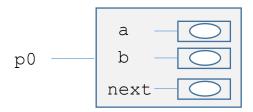
```
#include <stdio.h> // standard input/output
#include <stdlib.h> // standard library
                     // structure T
struct T {
                    // integer field
      int a;
                     // pointer to int
      int *b;
      struct T *next; // pointer to struct T
} ;
                      // p0's type is struct T
struct T p0;
                      // (not pointer)
                     // pointer to struct T
struct T *p1;
                     // pointer to struct T *
struct T **p2;
int *p;
int *q;
```

```
#include <stdio.h> // standard input/output
#include <stdlib.h> // standard library
struct T {
                     // structure T
                    // integer field
      int a;
                     // pointer to int
      int *b;
      struct T *next; // pointer to struct T
} ;
                      // p0's type is struct T
struct T p0;
                      // (not pointer)
                      // pointer to struct T
struct T *p1;
                     // pointer to struct T *
struct T **p2;
int *p;
                      // pointer to int
int *q;
                      // pointer to int
```

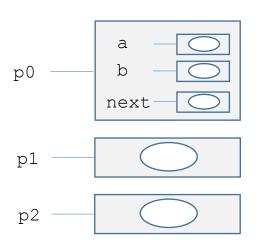
```
#include <stdio.h> // standard input/output
#include <stdlib.h> // standard library
struct T {
                     // structure T
                    // integer field
      int a;
      int *b;
                     // pointer to int
      struct T *next; // pointer to struct T
} ;
                      // p0's type is struct T
struct T p0;
                      // (not pointer)
                     // pointer to struct T
struct T *p1;
                     // pointer to struct T *
struct T **p2;
int *p;
                      // pointer to int
int *q;
                      // pointer to int
```

Let us draw the box-circle diagram at this point

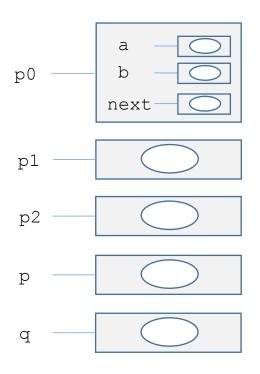
```
#include <stdio.h>
                      // standard input/output
#include <stdlib.h>
                      // standard library
struct T {
                       // structure T
                       // integer field
       int a;
       int *b;
                       // pointer to int
       struct T *next; // pointer to struct T
} ;
struct T p0;
                       // p0's type is struct T
                       // (not pointer)
                       // pointer to struct T
struct T *p1;
                       // pointer to struct T *
struct T **p2;
int *p;
                       // pointer to int
int *q;
                       // pointer to int
```



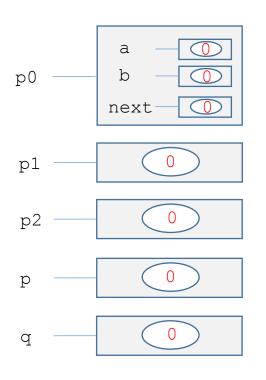
```
#include <stdio.h>
                      // standard input/output
#include <stdlib.h>
                     // standard library
struct T {
                       // structure T
                       // integer field
       int a;
       int *b;
                       // pointer to int
       struct T *next; // pointer to struct T
} ;
                       // p0's type is struct T
struct T p0;
                       // (not pointer)
                       // pointer to struct T
struct T *p1;
                      // pointer to struct T st
struct T **p2;
int *p;
                       // pointer to int
int *q;
                       // pointer to int
```



```
#include <stdio.h> // standard input/output
#include <stdlib.h> // standard library
struct T {
                       // structure T
                       // integer field
       int a;
       int *b;
                       // pointer to int
       struct T *next; // pointer to struct T
} ;
                       // p0's type is struct T
struct T p0;
                       // (not pointer)
                       // pointer to struct T
struct T *p1;
                       // pointer to struct T *
struct T **p2;
int *p;
                       // pointer to int
int *q;
                       // pointer to int
```



```
#include <stdio.h>
                       // standard input/output
#include <stdlib.h>
                      // standard library
                       // structure T
struct T {
                       // integer field
       int a;
                       // pointer to int
       int *b;
       struct T *next; // pointer to struct T
} ;
struct T p0;
                       // p0's type is struct T
                       // (not pointer)
                       // pointer to struct T
struct T *p1;
struct T **p2;
                       // pointer to struct T *
int *p;
                       // pointer to int
int *q;
                       // pointer to int
```



All values of global variables are initially 0 according to the C standard

p2

р

q

0

0

0

0

0

p1

p2

р

q

Mem1

b

next

```
int main()
                                         main()
{
 p1 = (struct T *) malloc(sizeof(struct T));
p2 = (struct T **) malloc(sizeof(struct T *));
p = (int *) malloc(sizeof(int));
q = (int *) malloc(sizeof(int));
 *p = *q;
                0
                                      @addr1
                0
  р0
          b
                0
         next
                                                   Mem1
                                        а
                                        b
            addr1
  p1
                                       next
              0
  p2
              0
  р
              0
```

q

```
int main()
                                         main()
{
p1 = (struct T *) malloc(sizeof(struct T));
p2 = (struct T **) malloc(sizeof(struct T *));
p = (int *) malloc(sizeof(int));
q = (int *) malloc(sizeof(int));
*p = *q;
                0
                                      @addr1
                0
 рО
          b
                0
         next
                                                   Mem1
                                        а
                                       b
            addr1
  p1
                                       next
                                      @addr2
            addr2
  p2
                                                   Mem2
              0
  р
```

0

q

```
int main()
                                          main()
{
p1 = (struct T *) malloc(sizeof(struct T));
p2 = (struct T **) malloc(sizeof(struct T *));
p = (int *) malloc(sizeof(int));
q = (int *) malloc(sizeof(int));
 *p = *q;
                 0
                                       @addr1
                 0
  р0
          b
                 0
          next
                                                     Mem1
                                         а
                                         b
            addr<del>1</del>
  p1
                                        next
                                       @addr2
             addr2
  p2
                                                     Mem2
             addr3
  р
                                       @addr3
```

0

q

Mem3

```
int main()
                                          main()
{
p1 = (struct T *) malloc(sizeof(struct T));
p2 = (struct T **) malloc(sizeof(struct T *));
p = (int *) malloc(sizeof(int));
q = (int *) malloc(sizeof(int));
 *p = *q;
                 0
                                        @addr1
                 0
  рO
           b
                 0
          next
                                                     Mem1
                                         а
                                         b
            addr<del>1</del>
  p1
                                        next
                                       @addr2
             addr2
  p2
                                                     Mem2
             addr3
  р
                                       @addr3
                                                     Mem3
            (addr4
  q
                                       @addr4
```

Mem4

```
int main()
                                          main()
p1 = (struct T *) malloc(sizeof(struct T));
p2 = (struct T **) malloc(sizeof(struct T *));
p = (int *) malloc(sizeof(int));
q = (int *) malloc(sizeof(int));
 *p = *q;
                 0
                                       @addr1
           b
                 р0
                 0
          next
                                                     Mem1
                                         а
                                         b
            addr<del>l</del>
  р1
                                        next
                                       @addr2
             addr2
  p2
                                                    Mem2
             addr3
  р
                                       @addr3
```

The values in the allocated locations are not initialized. So, I will denote them with ?#

(addr4

q

Mem3

Mem4

@addr4

```
int main()
                                          main()
p1 = (struct T *) malloc(sizeof(struct T));
p2 = (struct T **) malloc(sizeof(struct T *));
p = (int *) malloc(sizeof(int));
q = (int *) malloc(sizeof(int));
 *p = *q;
                @addr1
           b
                 р0
                 0
          next
                                                     Mem1
                                         а
                                         b
            addr<del>l</del>
  р1
                                        next
                                       @addr2
             addr2
  p2
                                                    Mem2
             addr3
  р
                                       @addr3
                                                     Mem3
            (addr4
  q
                                       @addr4
```

The values in the allocated locations are not initialized. So, I will denote them with ?#

Mem4

The ? to indicate the value is unknown

```
int main()
                                          main()
p1 = (struct T *) malloc(sizeof(struct T));
p2 = (struct T **) malloc(sizeof(struct T *));
p = (int *) malloc(sizeof(int));
q = (int *) malloc(sizeof(int));
 *p = *q;
                 0
                                       @addr1
           b
                 р0
                 0
          next
                                                     Mem1
                                         а
                                         b
            addr<del>1</del>
  р1
                                        next
                                       @addr2
             addr2
  p2
                                                    Mem2
             addr3
  р
                                       @addr3
                                                     Mem3
                                           ?1
            (addr4
  q
                                       @addr4
                                                     Mem4
```

Above, 3 of the unknown value are highlighted

?2

```
int main()
                                          main()
p1 = (struct T *) malloc(sizeof(struct T));
p2 = (struct T **) malloc(sizeof(struct T *));
p = (int *) malloc(sizeof(int));
q = (int *) malloc(sizeof(int));
 *p = *q;
                 0
                                       @addr1
           b
                 р0
                 0
          next
                                                     Mem1
                                         а
                                         b
            addr<del>l</del>
  р1
                                        next
                                       @addr2
             addr2
  р2
                                                     Mem2
             addr3
  р
                                       @addr3
                                                     Mem3
                                           ?1
            (addr4
  q
                                       @addr4
```

Above, 3 of the unknown value are highlighted
They are given different numbers because these
values need not be the same

Mem4

?2

```
int main()
                                          main()
p1 = (struct T *) malloc(sizeof(struct T));
p2 = (struct T **) malloc(sizeof(struct T *));
p = (int *) malloc(sizeof(int));
q = (int *) malloc(sizeof(int));
 *p = *q;
                 0
                                        @addr1
           b
                 0
  р0
                 0
          next
                                                     Mem1
                                         а
                                         b
            addr<del>1</del>
  р1
                                        next
                                       @addr2
             addr2
  p2
                                                     Mem2
             addr3
  р
                                       @addr3
                                                     Mem3
                                           ?1
            (addr4
  q
                                       @addr4
```

Now, we are ready to go back to our execution

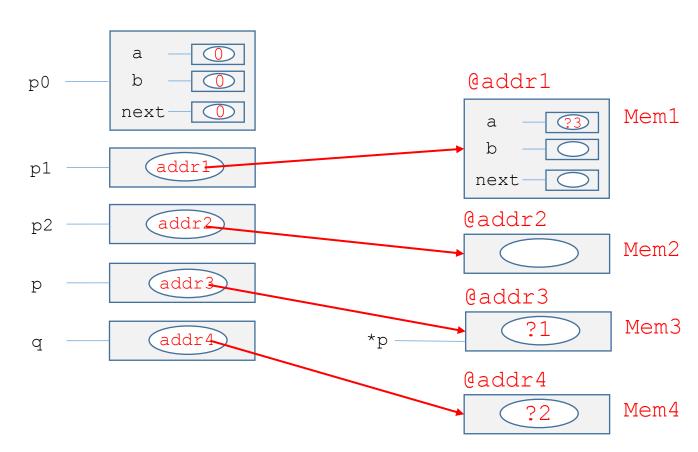
Mem4

?2

```
int main()
{
  p1 = (struct T *) malloc(sizeof(struct T));
  p2 = (struct T **) malloc(sizeof(struct T *));

  p = (int *) malloc(sizeof(int));
  q = (int *) malloc(sizeof(int));

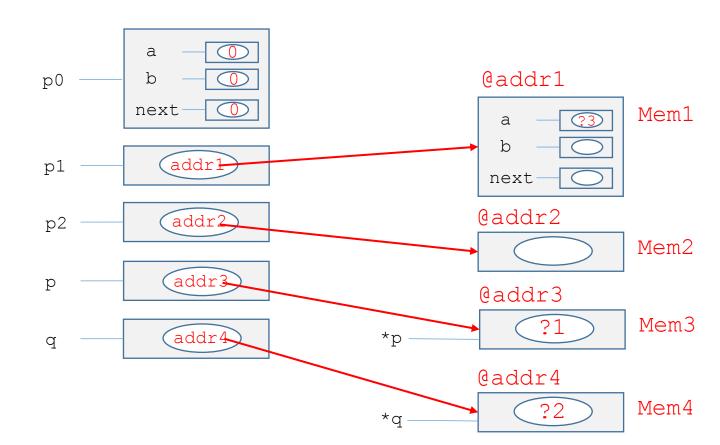
*p = *q;
```



```
int main()
{
  p1 = (struct T *) malloc(sizeof(struct T));
  p2 = (struct T **) malloc(sizeof(struct T *));

  p = (int *) malloc(sizeof(int));
  q = (int *) malloc(sizeof(int));

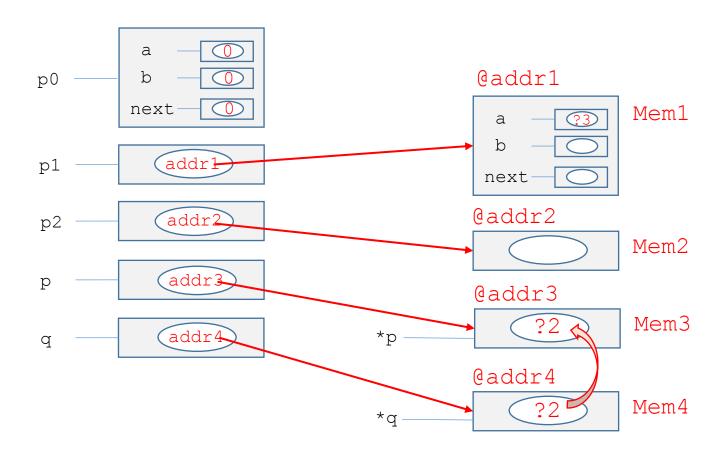
*p = *q;
```



```
int main()
{
  p1 = (struct T *) malloc(sizeof(struct T));
  p2 = (struct T **) malloc(sizeof(struct T *));

  p = (int *) malloc(sizeof(int));
  q = (int *) malloc(sizeof(int));
```

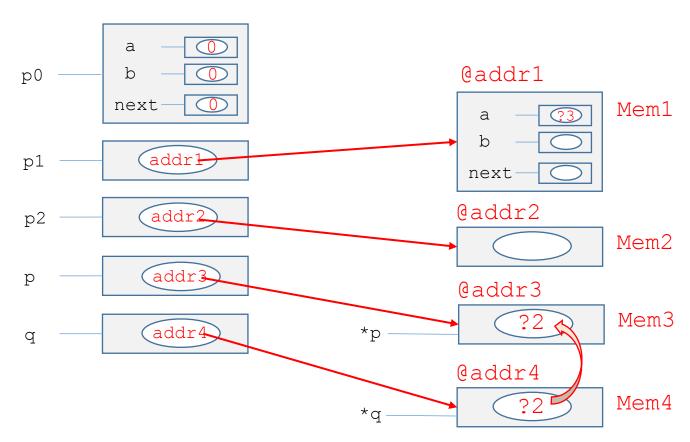
*p = *q;



```
int main()
{
  p1 = (struct T *) malloc(sizeof(struct T));
  p2 = (struct T **) malloc(sizeof(struct T *));

  p = (int *) malloc(sizeof(int));
  q = (int *) malloc(sizeof(int));
```





The values in $\underline{\text{Mem3}}$ and $\underline{\text{Mem4}}$ are the same unknown value

```
p0.next = p1;
(*p1).a = *p;
(*p1).next = &p0;
*p2 = (*p1).next;
                0
         а
                                         @addr1
                0
рO
         b
                0
        next
                                                       Mem1
                                          а
                                          b
           addr<del>1</del>
p1
                                         next
                                        @addr2
           addr2
p2
                                                       Mem2
            addr3
р
                                        @addr3
                                                       Mem3
                                             ?2
           addr4
                               *p -
q
                                        @addr4
                                                       Mem4
                                              ?2
                               *q-
```

main()

We continue with our program ...

int main()

```
int main()
                                             main()
{
  p0.next = p1;
  (*p1).a = *p;
  (*p1).next = &p0;
  *p2 = (*p1).next;
                  0
           а
                           p0.next
                                          @addr1
           b
                  0
  рО
                  0
          next
                                                        Mem1
                                            а
                                           b
             (addr<del>l</del>
  p1
                                          next
                                         @addr2
             addr2
  p2
                                                        Mem2
             addr3
  р
                                          @addr3
                                                        Mem3
                                              ?2
             addr4
                                 *p -
  q
                                         @addr4
```

Mem4

?2

```
main()
p0.next = p1;
(*p1).a = *p;
(*p1).next = &p0;
*p2 = (*p1).next;
               0
         а
                       p0.next
                                      @addr1
               0
        b
рO
        next
                                                   Mem1
                                       а
                                       b
          addr1
p1
                                      next
                                     @addr2
          addr2
p2
                                                   Mem2
           addr3
р
                                     @addr3
                                                   Mem3
                                         ?2
          addr4
                             *p -
q
                                     @addr4
```

Mem4

?2

int main()

```
main()
p0.next = p1;
(*p1).a = *p;
(*p1).next = &p0;
*p2 = (*p1).next;
               0
         а
                       p0.next
                                      @addr1
        b
               0
рО
        next
                                                   Mem1
                                       а
                                       b
          (addr1
p1
                                      next
                                     @addr2
           addr2
p2
                                                   Mem2
           addr3
р
                                     @addr3
                                                   Mem3
                                         ?2
          addr4
                             *p -
q
                                     @addr4
```

Mem4

?2

int main()

```
int main()
                                             main()
{
  p0.next = p1;
  (*p1).a = *p;
  (*p1).next = &p0;
  *p2 = (*p1).next;
                  0
           а
                           p0.next
                                          @addr1
           b
                  0
  рО
          next
                                                        Mem1
                                            а
                                            b
             (addr<del>l</del>
  p1
                                  *p1
                                           next
                                          @addr2
              addr2
  p2
                                                        Mem2
              addr3
  р
                                          @addr3
                                                         Mem3
                                              ?2
             addr4
                                 *p -
  q
                                          @addr4
```

Mem4

?2

```
int main()
                                             main()
  p0.next = p1;
  (*p1).a = *p;
  (*p1).next = &p0;
  *p2 = (*p1).next;
                                                      (*p1).a
                  0
           а
                           p0.next
                                          @addr1
           b
                  0
  рО
                                                        Mem1
          next
                                            а
                                           b
             (addr<del>l</del>
  p1
                                  *p1
                                           next
                                          @addr2
             addr2
  p2
                                                        Mem2
             addr3
  р
                                          @addr3
                                                        Mem3
                                              ?2
             addr4
                                 *p
  q
                                          @addr4
```

Mem4

?2

```
int main()
                                             main()
{
  p0.next = p1;
  (*p1).a = *p;
  (*p1).next = &p0;
  *p2 = (*p1).next;
                                                      (*p1).a
                  0
           а
                           p0.next
                                          @addr1
           b
                  0
  рO
                                                        Mem1
          next
                                            а
                                            b
             (addr<del>l</del>
  p1
                                  *p1
                                           next
                                          @addr2
              addr2
  p2
                                                        Mem2
              addr3
  р
                                          @addr3
                                                         Mem3
             addr4
                                 *p
  q
                                          @addr4
```

Mem4

?2

```
main()
{
  p0.next = p1;
  (*p1).a = *p;
  (*p1).next = &p0;
  *p2 = (*p1).next;
                                                      (*p1).a
                  0
           а
                           p0.next
                                          @addr1
           b
                  0
  рО
                                                        Mem1
          next
                                            а
                                            b
             (addr<del>l</del>
  p1
                                  *p1
                                           next
                                          @addr2
              addr2
  p2
                                                        Mem2
              addr3
  р
                                          @addr3
                                                         Mem3
                                              ?2
             addr4
                                 *p
  q
```

@addr4

?2

Mem4

int main()

```
main()
p0.next = p1;
(*p1).a = *p;
(*p1).next = &p0;
*p2 = (*p1).next;
                                                    (*p1).a
                0
         а
                         p0.next
                                         @addr1
         b
                0
рО
                                                       Mem1
        next
                                          а
                                          b
           (addr<del>l</del>
p1
                                *p1
                                         next
                            (*p1).next
                                        @addr2
            addr2
p2
                                                       Mem2
            addr3
р
                                        @addr3
```

*p

*q-

addr4

Mem3

Mem4

?2

?2

@addr4

int main()

{

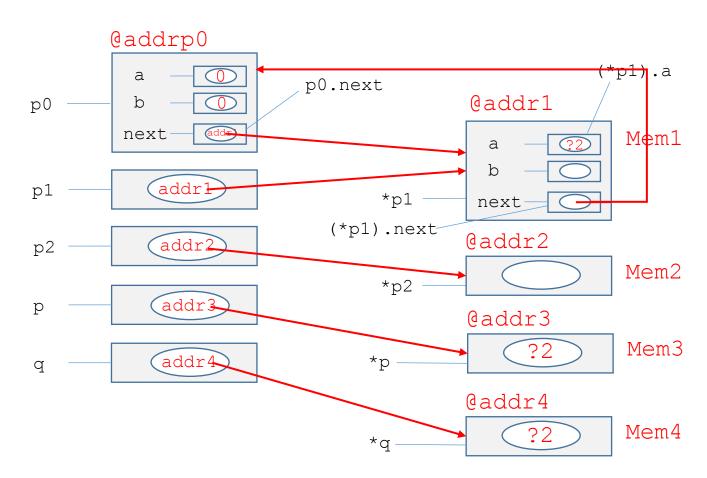
q

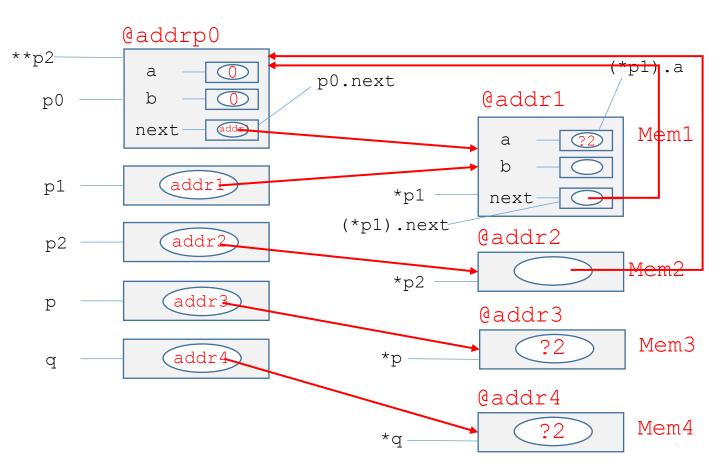
```
int main()
                                             main()
  p0.next = p1;
  (*p1).a = *p;
  (*p1).next = &p0;
                      //&p0 = <code>@addrp0</code>
  *p2 = (*p1).next;
         @addrp0
                                                     (*p1).a
                  0
           a
                           p0.next
                                          @addr1
                  0
  рO
           b
          next
                                                        Mem1
                                           а
                                           b
             addr1
  p1
                                  *p1
                                          next
                             (*p1).next
                                         @addr2
             addr2
  p2
                                                        Mem2
             addr3
  р
                                         @addr3
                                                        Mem3
                                              ?2
             addr4
                                 *p -
  q
                                         @addr4
                                                        Mem4
                                               ?2
                                 *q-
```

```
int main()
                                             main()
  p0.next = p1;
  (*p1).a = *p;
  (*p1).next = &p0;
                       //&p0 = @addrp0
  *p2 = (*p1).next;
         @addrp0
                                                       <del>'p1)</del>.a
                  0
                           p0.next
                                          @addr1
                  0
  рO
           b
          next
                                                        Mem1
                                            а
                                            b
             addr1-
  p1
                                  *p1
                                           next
                             (*p1).next
                                          @addr2
              addr2
  р2
                                                        Mem2
              addr3
  р
                                          @addr3
                                                         Mem3
             (addr4
                                 *p
  q
                                          @addr4
                                                        Mem4
                                               ?2
                                 *q-
```

{

(*p1).next is the same as p1->next p1->next is syntactic sugar for (*p1).next





&p and p are not the same

&p is an r-value

&p is just a number

It is the name of a location

*&p is an alias of p, but *&p is not the same as &p

*&p = ... ok

&p = ... not ok

```
p0.next = p1;
(*p1).a = *p;
(*p1).next = &p0;
                    //&p0 = @addrp0
*p2 = (*p1).next;
       @addrp0
                                                    <del>(*p1)</del>.a
                a
                         p0.next
                                        @addr1
рО
         b
                next
                                                      Mem1
                                          а
                                          b
           addr1-
p1
                                *p1
                                         next
                           (*p1).next
                                        @addr2
           addr2
р2
                                *p2
           addr3
р
                                        @addr3
                                                      Mem3
                                            ?2
           (addr4
                               *p -
q
                                        @addr4
                                                      Mem4
                                             ?2
                               *q-
```

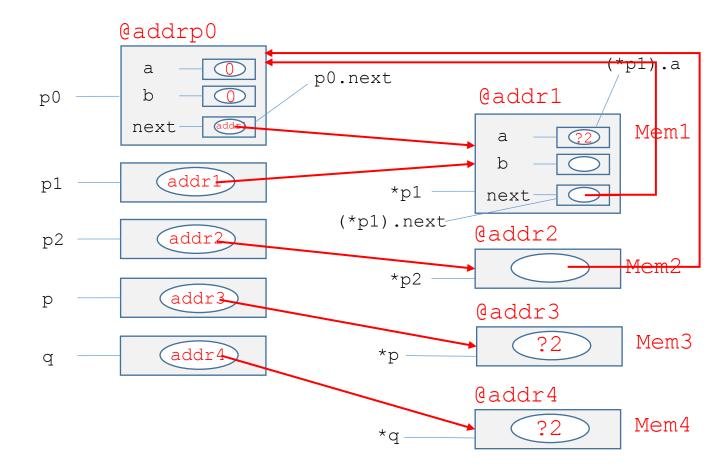
main()

We continue with our program ...

int main()

```
int main()
    { // NEW SCOPE
      struct T *a[5];
      a[0] = (struct T*) malloc(sizeof(struct T));
      p2 = &(a[0]);
      (*a[0]).next = p1;
```

{



We continue with our program ... with new declaration and statements

```
int main()
    { // NEW SCOPE
      struct T *a[5];
      a[0] = (struct T*) malloc(sizeof(struct T));
      p2 = &(a[0]);
      (*a[0]).next = p1;
         @addrp0
                                                    <del>(*p1)</del>.a
           а
                 0
                          p0.next
                                         @addr1
           b
                 рO
                 adde
          next
                                                      Mem1
                                                 ?2
                                          b
```

*p1 -

*p2

(*p1).next

*p -

*q-

next

@addr2

@addr3

@addr4

?2

?2

Mem3

Mem4

addr1

addr2

addr3

addr4

{

p1

p2

р

q

```
int main()
{
       struct T *a[5];
       a[0] = (struct T*) malloc(sizeof(struct T));
       p2 = &(a[0]);
       (*a[0]).next = p1;
         @addrp0
                                                       <del>(*p1)</del>.a
            а
                  0
                            p0.next
                                           @addr1
           b
                  0
  рO
                  adde
           next
                                                         Mem1
                                                   ?2
                                             b
              addr1
  p1
                                   *p1 -
                                            next
                              (*p1).next
                                           @addr2
              addr2
  p2
                                   *p2
              addr3
  р
                                           @addr3
                                                          Mem3
                                               ?2
              addr4
                                  *p -
  q
                                           @addr4
                                                         Mem4
                                                ?2
                                  *q-
a[0]
a[1]
a[2]
a[3]
a[4]
```

```
int main()
{
       struct T *a[5];
       a[0] = (struct T*) malloc(sizeof(struct T));
       p2 = &(a[0]);
       (*a[0]).next = p1;
         @addrp0
                                                       <del>(*p1)</del>.a
                  0
            а
                           p0.next
                                           @addr1
           b
                  0
  рO
                  adde
           next
                                                         Mem1
                                                   ?2
                                            b
              addr1
  p1
                                   *p1 -
                                            next
                              (*p1).next
                                           @addr2
              addr2
  p2
                                   *p2
              addr3
  р
                                           @addr3
                                                          Mem3
                                               ?2
             addr4
                                 *p -
  q
                                           @addr4
                                                         Mem4
                                               ?2
                                 *q-
a[0]
                                           @addr5
a[1]
                                                         Mem5
                                             а
a[2]
                                             b
a[3]
                                            next
a[4]
```

```
int main()
{
       struct T *a[5];
       a[0] = (struct T*) malloc(sizeof(struct T));
       p2 = &(a[0]);
       (*a[0]).next = p1;
         @addrp0
                                                       <del>(*p1)</del>.a
                  0
            а
                            p0.next
                                           @addr1
           b
                  0
  рO
                  adde
           next
                                                         Mem1
                                                   ?2
                                             b
              addr1
  p1
                                   *p1 -
                                            next
                              (*p1).next
                                           @addr2
              addr2
  p2
                                   *p2
              addr3
  р
                                           @addr3
                                                          Mem3
                                               ?2
             addr4
                                  *p -
  q
                                           @addr4
                                                         Mem4
                                                ?2
                                  *q
              addr5
a[0]
                                           @addr5
a[1]
                                                         Mem5
                                             а
a[2]
a[3]
                                            next
a[4]
```

```
int main()
{
       struct T *a[5];
       a[0] = (struct T*) malloc(sizeof(struct T));
       p2 = &(a[0]);
       (*a[0]).next = p1;
          @addrp0
                                                         <del>(*p1)</del>.a
            а
                   0
                            p0.next
                                             @addr1
            b
                   0
  рO
                   adde
           next
                                                           Mem1
                                                     ?2
                                              b
              addr1
  p1
                                    *p1 -
                                             next
                               (*p1).next
                                            @addr2
              addra[<del>0]</del>
  p2
              addr3
  р
                                            @addr3
                                                            Mem3
                                                 ?2
              addr4
                                   *p -
  q
                                            @addr4
                                                           Mem4
                                                 ?2
                                   *q
              addr5
a[0]
                                             @addr5
a[1]
                                                           Mem5
                                               а
a[2]
a[3]
                                             next
a[4]
```

```
int main()
{
       struct T *a[5];
       a[0] = (struct T*) malloc(sizeof(struct T));
       p2 = &(a[0]);
       (*a[0]).next = p1;
         @addrp0
                                                        <del>(*p1)</del>.a
                  0
                            p0.next
                                           @addr1
                  0
            b
  рO
                  add
           next
                                                          Mem1
                                                    ?2
                                             b
              addr1
  p1
                                   *p1 -
                                            next
                              (*p1).next
                                           @addr2
              addra[<del>0]</del>
  p2
              addr3
  р
                                           @addr3
                                                          Mem3
                                                ?2
              addr4
                                  *p -
  q
                                           @addr4
                                                          Mem4
                                  *q
              addr5
a[0]
                                           @addr5
a[1]
                                                          Mem5
a[2]
a[3]
                                            next
a[4]
                          Mem2 is no longer accessible
```

```
int main()
{
       struct T *a[5];
       a[0] = (struct T*) malloc(sizeof(struct T));
       p2 = &(a[0]);
       (*a[0]).next = p1;
          @addrp0
                                                         <del>(*p1)</del>.a
                   0
                             p0.next
                                             @addr1
            b
                   0
  рO
                   adde
           next
                                                            Mem1
                                                     ?2
                                              b
              addr1
  p1
                                    *p1 -
                                             next
                               (*p1).next
                                            @addr2
              addra[<del>0]</del>
  p2
              addr3
  р
                                            @addr3
                                                 ?2
                                                            Mem3
              addr4
                                   *p -
  q
                                            @addr4
                                                            Mem4
                                                 ?2
                                   *q-
              addr5
a[0]
                                             @addr5
a[1]
                                                            Mem5
                                               а
a[2]
                               *a[0] -
a[3]
                                              next
a[4]
```

```
int main()
{
       struct T *a[5];
       a[0] = (struct T*) malloc(sizeof(struct T));
       p2 = &(a[0]);
       (*a[0]).next = p1;
          @addrp0
                                                          <del>(*p1)</del>.a
                   0
                             p0.next
                                             @addr1
            b
                   0
  рO
                   adde
           next
                                                            Mem1
                                                      ?2
                                               b
              addr1
  p1
                                    *p1 -
                                              next
                               (*p1).next
                                             @addr2
              addra[<del>0]</del>
  p2
               addr3
  р
                                             @addr3
                                                            Mem3
                                                  ?2
              addr4
                                   *p -
  q
                                             @addr4
                                                            Mem4
                                   *q-
               addr5
a[0]
                                             @addr5
a[1]
                                                            Mem5
                                               а
a[2]
                                *a[0] -
a[3]
                                              next
a[4]
                                    *a[0].next
```

```
int main()
{
       struct T *a[5];
       a[0] = (struct T*) malloc(sizeof(struct T));
       p2 = &(a[0]);
       (*a[0]).next = p1;
         @addrp0
                                                       <del>(*p1)</del>.a
                  0
                            p0.next
                                           @addr1
           b
                  0
  рO
                  adde
           next
                                                          Mem1
                                                    ?2
                                             b
              addr1
  p1
                                   *p1 -
                                            next
                              (*p1).next
                                           @addr2
              addr
  p2
              addr3
  р
                                           @addr3
                                                          Mem3
                                                ?2
             addr4
                                  *p -
  q
                                           @addr4
                                                          Mem4
                                  *q
                                                ?2
              addr5
a[0]
                                           @addr5
a[1]
                                                          Mem5
a[2]
                              *a[0] -
a[3]
                                            next
a[4]
                                  *a[0].next
```

```
int main()
{
       struct T *a[5];
       a[0] = (struct T*) malloc(sizeof(struct T));
       p2 = &(a[0]);
       (*a[0]).next = p1;
          @addrp0
                                                          <del>(*p1)</del>.a
                   0
                             p0.next
                                             @addr1
            b
                   0
  рO
                   adde
           next
                                                            Mem1
                                                      ?2
                                               b
              addr1
  p1
                                    *p1 -
                                              next
                               (*p1).next
                                             @addr2
              addra[<del>0]</del>
  p2
               addr3
  р
                                             @addr3
                                                            Mem3
                                                  ?2
              addr4
                                   *p -
  q
                                             @addr4
                                                            Mem4
                                   *q-
               addr5
a[0]
                                             @addr5
a[1]
                                                            Mem5
                                               а
a[2]
                                *a[0] -
a[3]
                                              next
```

*a[0].next

a[4]

```
int main()
{
       struct T *a[5];
       a[0] = (struct T*) malloc(sizeof(struct T));
       p2 = &(a[0]);
       (*a[0]).next = p1;
          @addrp0
                                                         <del>(*p1)</del>.a
                   0
            а
                             p0.next
                                             @addr1
                   0
            b
  рO
                   add
           next
                                                            Mem1
                                                     ?2
                                              b
              addr1
  p1
                                    *p1 -
                                             next
                               (*p1).next
                                            @addr2
              addra[<del>0</del>
  p2
              addr3
  р
                                            @addr3
                                                            Mem3
                                                 ?2
              addr4
                                   *p -
  q
                                            @addr4
                                                            Mem4
                                                 ?2
                                   *q
              addr5
a[0]
                                             @addr5
a[1]
                                                            Mem5
                                               а
a[2]
                                               b
                               *a[0]
a[3]
                                              next
a[4]
                                   *a[0].next
```

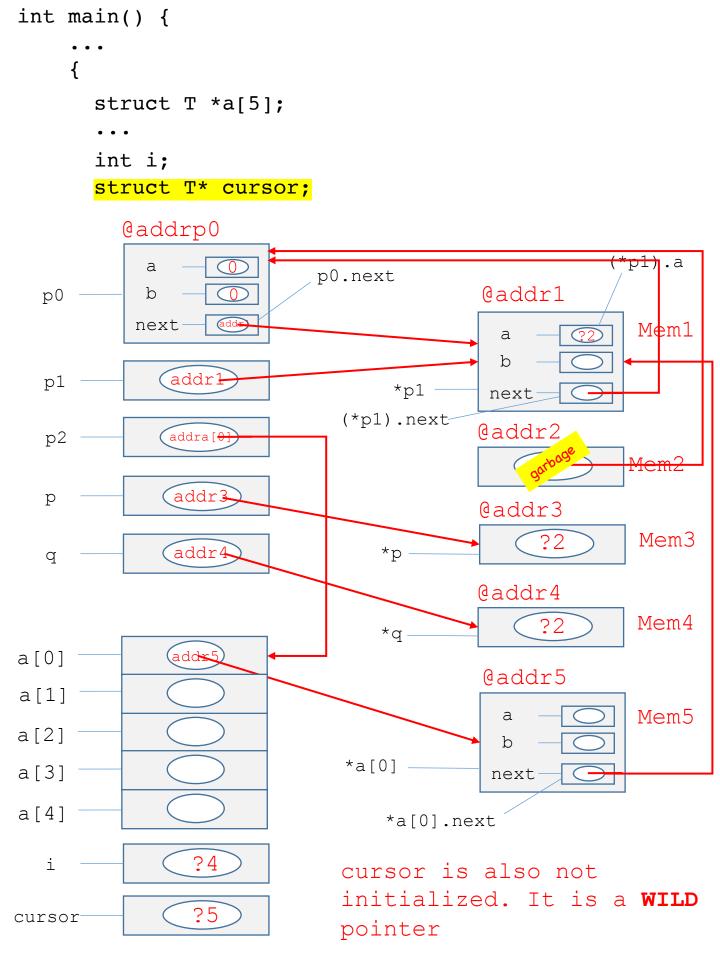
```
int main() {
       struct T *a[5];
       int i;
       struct T* cursor;
          @addrp0
                                                           <del>(*p1)</del>.a
                    0
                              p0.next
                                               @addr1
                    0
            b
  рO
                    addr
           next
                                                              Mem1
                                                        ?2
              addr1
  p1
                                      *p1 -
                                               next
                                 (*p1).next
                                              @addr2
               addra[<del>0]</del>
  p2
               addr3
  р
                                              @addr3
                                                               Mem3
                                                    ?2
              (addr4
                                    *p -
  q
                                              @addr4
                                                              Mem4
                                    *q-
               addr5
a[0]
                                               @addr5
a[1]
                                                              Mem5
a[2]
                                                 b
                                 *a[0]
a[3]
                                                next
a[4]
                                     *a[0].next
```

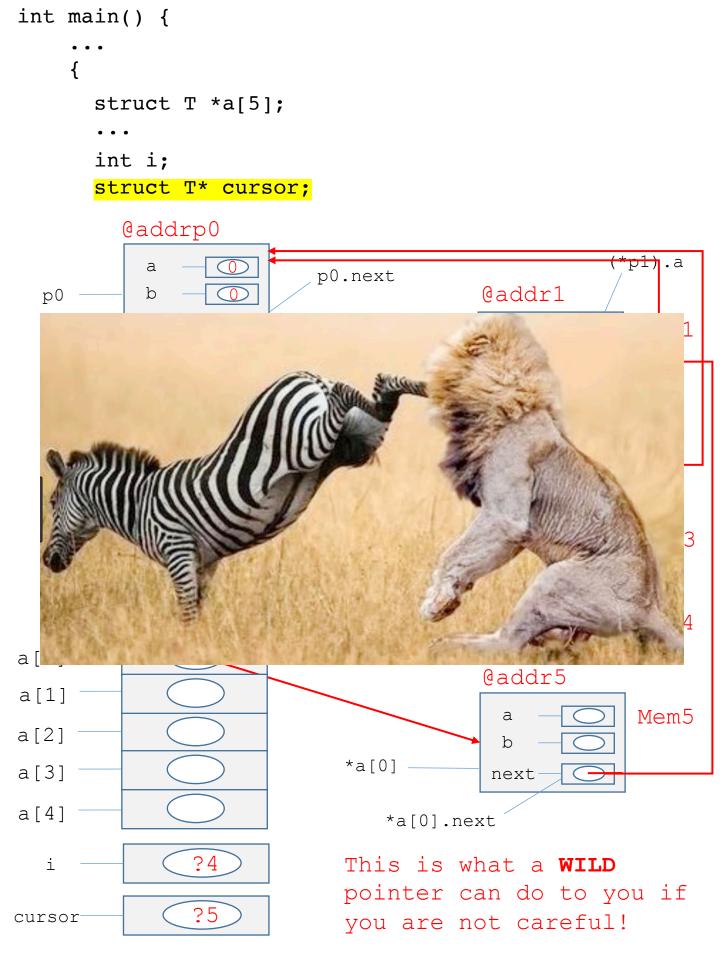
We continue with our program ... with new declarations

```
int main() {
       struct T *a[5];
       int i;
       struct T* cursor;
          @addrp0
                                                        <del>(*p1)</del>.a
                   0
                            p0.next
                                            @addr1
                   0
            b
  рO
                   addr
           next
                                                           Mem1
                                                    ?2
                                             b
             (addr1
  p1
                                   *p1 -
                                             next
                               (*p1).next
                                            @addr2
             addra[<del>0]</del>
  p2
              addr3
  р
                                            @addr3
                                                           Mem3
                                                 ?2
              addr4
                                  *p -
  q
                                            @addr4
                                                           Mem4
                                  *q-
              addr5
a[0]
                                            @addr5
a[1]
                                                           Mem5
a[2]
                                              b
                               *a[0]
a[3]
                                             next
a[4]
                                   *a[0].next
                ?4
  i
                              i is not initialized
                              because it is a local
                              variable
```

```
int main() {
       struct T *a[5];
       int i;
       struct T* cursor;
          @addrp0
                                                          <del>(*p1)</del>.a
                   0
                             p0.next
                                              @addr1
                   b
  рO
                   addr
           next
                                                             Mem1
                                                      ?2
                                               а
                                               b
              addr1
  p1
                                     *p1 -
                                              next
                                (*p1).next
                                             @addr2
              addra[<del>0]</del>
  p2
               addr3
  р
                                             @addr3
                                                             Mem3
                                                  ?2
              (addr4
                                    *p -
  q
                                             @addr4
                                                             Mem4
                                    *q-
               addr5
a[0]
                                              @addr5
a[1]
                                                             Mem5
a[2]
                                               b
                                *a[0]
a[3]
                                              next
a[4]
                                    *a[0].next
                 ?4
  i
```

```
int main() {
       struct T *a[5];
       int i;
       struct T* cursor;
          @addrp0
                                                           <del>(*p1)</del>.a
                    0
                              p0.next
                                              @addr1
                    0
            b
  рO
                    addr
           next
                                                             Mem1
                                                       ?2
                                                а
                                                b
              addr1
  p1
                                     *p1 -
                                               next
                                (*p1).next
                                              @addr2
              addra[<del>0]</del>
  p2
               addr3
  р
                                              @addr3
                                                              Mem3
                                                   ?2
              addr4
                                    *p -
  q
                                              @addr4
                                                             Mem4
                                    *q-
               addr5
a[0]
                                              @addr5
a[1]
                                                             Mem5
a[2]
                                                b
                                *a[0]
a[3]
                                               next
a[4]
                                     *a[0].next
                 ?4
  i
                 ?5
cursor
```





```
struct T *a[5];
       int i;
       struct T* cursor;
       struct T **b[5];
          @addrp0
                                                           <del>(*p1)</del>.a
                    0
                              p0.next
                                              @addr1
                    0
             b
  рO
                    addr
            next
                                                              Mem1
                                                       ?2
                                                а
                                                b
              addr1
  p1
                                     *p1 -
                                               next
                                (*p1).next
                                              @addr2
              addra[<del>0]</del>
  p2
               addr3
  р
                                              @addr3
                                                              Mem3
                                                   ?2
              addr4
                                    *p -
   q
                                              @addr4
                                                              Mem4
                                    *q-
               addr5
a[0]
                                              @addr5
a[1]
                                                              Mem5
                                                а
a[2]
                                                b
                                 *a[0]
a[3]
                                               next
a[4]
                                     *a[0].next
                 ?4
   i
                 ?5
cursor
```

```
struct T *a[5];
       int i;
       struct T* cursor;
       struct T **b[5];
          @addrp0
                                                         <del>(*p1)</del>.a
                   0
                             p0.next
                                             @addr1
                   0
            b
  р0
                   addr
           next
                                                            Mem1
                                                     ?2
                                               а
                                              b
              addr1
  p1
                                    *p1 -
                                             next
                               (*p1).next
                                            @addr2
              addra[<del>0]</del>
  p2
              addr3
  р
                                            @addr3
                                                            Mem3
                                                 ?2
              (addr4
                                   *p -
  q
                                            @addr4
                                                            Mem4
                                   *q-
              addr5
a[0]
                                             @addr5
a[1]
                                                            Mem5
a[2]
                                              b
                               *a[0]
a[3]
                                              next
a[4]
                                   *a[0].next
                 ?4
  i
                              We continue with another
                              declaration.
                 ?5
cursor
```

```
struct T *a[5];
       int i;
       struct T* cursor;
       struct T **b[5];
          @addrp0
                                                         <del>(*p1)</del>.a
                   0
                             p0.next
                                             @addr1
                   b
  р0
                   addr
           next
                                                            Mem1
                                                     ?2
                                              а
                                              b
              (addr1
  p1
                                    *p1 -
                                             next
                               (*p1).next
                                            @addr2
              addra[<del>0]</del>
  p2
              addr3
  р
                                            @addr3
                                                            Mem3
                                                 ?2
              (addr4
                                   *p -
  q
                                            @addr4
                                                            Mem4
                                   *q-
              addr5
a[0]
                                             @addr5
a[1]
                                                            Mem5
a[2]
                                              b
                               *a[0]
a[3]
                                             next
a[4]
                                   *a[0].next
                 ?4
  i
                             Since the picture is
                             getting busy ...
                 ?5
cursor
```

```
struct T *a[5];
       int i;
       struct T* cursor;
       struct T **b[5];
          @addrp0
                                                       <del>(*p1)</del>.a
                  0
                            p0.next
                                           @addr1
                  b
  р0
                  addr
           next
                                                          Mem1
                                                   ?2
                                             а
                                             b
             addr1
  p1
                                   *p1 -
                                            next
                              (*p1).next
                                           @addr2
             addra[<del>0]</del>
  p2
              addr3
  р
                                           @addr3
                                                ?2
                                                          Mem3
             (addr4
                                  *p -
  q
                                           @addr4
                                                          Mem4
                                  *q-
              addr5
a[0]
                                           @addr5
a[1]
                                                          Mem5
a[2]
                                             b
                              *a[0]
a[3]
                                            next
a[4]
                                  *a[0].next
                ?4
  i
                                 I will only show the
                            parts relevant to the
                ?5
cursor
                            next piece of code ...
```

```
struct T *a[5];
     int i;
     struct T* cursor;
     struct T **b[5];
       @addrp0
                                                      <del>(*p1)</del>.a
                0
          а
                          p0.next
                                         @addr1
         b
                0
рO
                addr
        next
                                                        Mem1
                                                  ?2
                                           а
                                           b
           addr1
p1
                                 *p1 -
                                          next
                            (*p1).next
                                               @addr5
                                                          Mem5
                                                а
                                                b
                                  addr5
                                               next
                      a[0]
                      a[1]
                      a[2]
                      a[3]
                      a[4]
```

```
struct T *a[5];
     int i;
     struct T* cursor;
    struct T **b[5];
       @addrp0
                                                     <del>(*p1)</del>.a
                0
          а
                          p0.next
                                         @addr1
         b
                0
рO
                addr
        next
                                                        Mem1
                                                  ?2
                                           а
                                           b
           addr1
p1
                                 *p1 -
                                          next
                            (*p1).next
                                              @addr5
                                                          Mem5
                                                а
                                                b
                                  addr5
                                               next
                      a[0]
                      a[1]
                      a[2]
                      a[3]
                      a[4]
```

```
struct T *a[5];
      int i;
      struct T* cursor;
      struct T **b[5];
         @addrp0
                 0
                                         @addr1
           b
  рO
          next
                                                       Mem1
                                           а
                                           b
            addr1
  р1
                                 *p1
                                          next
                             (*p1).next
                                              @addr5
                                                         Mem5
                                                а
                                                b
                                               next
b[0]
                       a[0]
                       a[1]
b[1]
b[2]
                       a[2]
b[3]
                       a[3]
b[4]
                       a[4]
```

i ?4

```
struct T *a[5];
       int i;
       struct T* cursor;
       struct T **b[5];
         @addrp0
                  0
                                           @addr1
                  0
           b
  рO
                  adde
          next
                                                         Mem1
                                                   (?2)
                                            b
             (addr1
  p1
                                  *p1 -
                                           next
                              (*p1).next-
                                                @addr5
                                                           Mem5
                                                 а
                                                 b
                                    add15
                                                next
b[0]
                       a[0]
b[1]
                        a[1]
b[2]
                       a[2]
b[3]
                        a[3]
b[4]
                        a[4]
```

... and we continue with our program ...

i ?4

```
for (i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
    (*a[i]).next = a[i-1];
    (*a[i]).a = i;
    b[i] = &a[i];
    (**b[i]).next = *b[i];
 (*p1).next = a[2];
         @addrp0
                 а
                                        @addr1
           b
                 0
  рO
                                                     Mem1
                                         а
                                               ?2
          next
                                         b
            (addr1
  p1
                                        next
                                            @addr5
                                                       Mem5
                                              а
                                              b
                                             next
                                 addr5
b[0]
                      a[0]
b[1]
                      a[1]
b[2]
                      a[2]
b[3]
                      a[3]
b[4]
                      a[4]
             ?4
i
```

```
for (i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
    (*a[i]).next = a[i-1];
    (*a[i]).a = i;
    b[i] = &a[i];
    (**b[i]).next = *b[i];
 (*p1).next = a[2];
         @addrp0
                 а
                                        @addr1
           b
                 0
  рO
                                                     Mem1
                                         а
                                                ?2
          next
                                         b
            (addr1
  p1
                                        next
                                            @addr5
                                                       Mem5
                                              а
                                              b
                                             next
                                 addr5
b[0]
                      a[0]
b[1]
                      a[1]
b[2]
                      a[2]
b[3]
                      a[3]
b[4]
                      a[4]
i
```

```
for (i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
    (*a[i]).next = a[i-1];
    (*a[i]).a = i;
    b[i] = &a[i];
    (**b[i]).next = *b[i];
 (*p1).next = a[2];
         @addrp0
                 а
                                        @addr1
           b
                 0
  рO
                                                      Mem1
                                          а
                                                ?2
          next
                                          b
            (addr1
  р1
                                         next
                                             @addr5
                                                        Mem5
                                               а
                                               b
                                              next
                                  addr5
b[0]
                      a[0]
                                             @addr6
                                                        Mem6
                                  (addr6
b[1]
                      a[1]
                                               а
b[2]
                      a[2]
                                               b
b[3]
                      a[3]
                                              next
b[4]
                      a[4]
             1
i
```

```
for (i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
    (*a[i]).next = a[i-1]; // a[i]->next
    (*a[i]).a = i;
                                 //a[i]->a
    b[i] = &a[i];
    (**b[i]).next = *b[i];
 (*p1).next = a[2];
         @addrp0
                 а
                                        @addr1
           b
                 0
  рO
                                                     Mem1
                                         а
                                               ?2
          next
                                         b
            (addr1
  р1
                                        next
                                            @addr5
                                                       Mem5
                                              а
                                              b
                                             next
                                 addr5
b[0]
                      a[0]
                                             @addr6
                                                       Mem 6
                                 addr6
                      a[1]
b[1]
                                              а
b[2]
                      a[2]
                                              b
b[3]
                      a[3]
                                             next
b[4]
                      a[4]
             1
i
```

```
for (i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
    (*a[i]).next = a[i-1];
    (*a[i]).a = i;
    b[i] = &a[i];
    (**b[i]).next = *b[i];
 (*p1).next = a[2];
         @addrp0
                  а
                                          @addr1
           b
                  0
  рO
                                                        Mem1
                                           а
                                                  ?2
          next
                                           b
            (addr1
  p1
                                          next
                                              @addr5
                                                          Mem5
                                                а
                                                b
                                               next
                                   addr5
b[0]
                       a[0]
                                               @addr6
                                                          Mem<sub>6</sub>
                                   (addr6
                       a[1]
b[1]
                                                а
b[2]
                       a[2]
                                                b
b[3]
                       a[3]
                                                next
b[4]
                       a[4]
              1
i
```

```
(i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
     (*a[i]).next = a[i-1];
    (*a[i]).a = i;
    b[i] = &a[i];
    (**b[i]).next = *b[i];
 (*p1).next = a[2];
          @addrp0
                   @addr1
                   0
  рO
            b
                                                          Mem1
           next
                                             b
              addr1
  р1
                                            next
 b[i] is of type struct T **
                                                 @addr5
                                                            Mem5
 a[i] is of type struct T *
                                                  а
                                                  b
                                                 next
                                    addr5
b[0]
                        a[0]
                                                 @addr6
                                                            Mem<sub>6</sub>
                                    addr6
b[1]
                        a[1]
b[2]
                        a[2]
                                                  b
b[3]
                        a[3]
                                                  next
b[4]
                        a[4]
                              *((**b[i]).next)
                                              name of mem5
              1
 i
                              *((*b[i])->next)
                                              name of mem5
```

```
for (i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
    (*a[i]).next = a[i-1];
    (*a[i]).a = i;
    b[i] = &a[i];
    (**b[i]).next = *b[i];
 (*p1).next = a[2];
         @addrp0
                 а
                                        @addr1
           b
                 0
  рO
                                                      Mem1
                                          а
                                                (?2)
          next
                                         b
            (addr1
  p1
                                         next
                                             @addr5
                                                       Mem5
                     *b[i]
                                              а
                                              b
                                              next
                                 addr5
b[0]
                      a[0]
                                             @addr6
                                                        Mem 6
                                  addr6
b[1]
                      a[1]
                                               а
b[2]
                      a[2]
                                               b
b[3]
                      a[3]
                                              next
b[4]
                      a[4]
                                            **b[i].next
             1
i
```

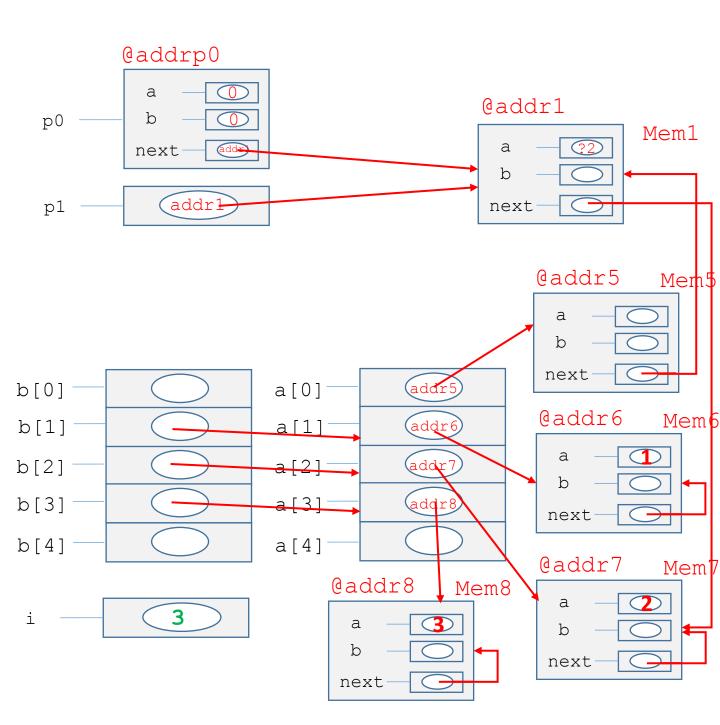
```
for (i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
    (*a[i]).next = a[i-1];
    (*a[i]).a = i;
    b[i] = &a[i];
    (**b[i]).next = *b[i];
 (*p1).next = a[2];
         @addrp0
                 а
                                        @addr1
           b
                 0
  рO
                                                      Mem1
                                          а
                                                (?2)
          next
                                         b
            (addr1
  p1
                                         next
                                             @addr5
                                                       Mem5
                     *b[i]
                                              а
                                              b
                                             next
                                 addr5
b[0]
                      a[0]
                                             @addr6
                                                        Mem6
                                 addr6
b[1]
                      a[1]
                                               а
b[2]
                      a[2]
                                              b
b[3]
                      a[3]
                                              next
b[4]
                      a[4]
                                            **b[i].next
             1
i
```

```
for (i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
    (*a[i]).next = a[i-1];
    (*a[i]).a = i;
    b[i] = &a[i];
    (**b[i]).next = *b[i];
        // at the end of the loop
 (*p1).next = a[2];
         @addrp0
                 а
                                         @addr1
  рО
           b
                 0
                                                       Mem1
                                          а
                                                (?2)
          next
                                          b
            (addr1
  p1
                                         next
                                             @addr5
                                                        Mem5
                                               а
                                               b
                                              next
                                  addr5
b[0]
                      a[0]
                                              @addr6
                                                        Mem6
                                  (addr6
b[1]
                      a[1]
                                               а
                                  addr7
b[2]
                      a[2]
                                               b
                                  addr8
b[3]
                      a[3]
                                              next
                      a[4]
b[4]
                                              @addr7
                                                        Mem7
                           @addr8
                                     Mem8
                                               а
             3
i
                             а
                                               b
                             b
                                              next
                            next
```

```
for (i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
    (*a[i]).next = a[i-1];
    (*a[i]).a = i;
    b[i] = &a[i];
    (**b[i]).next = *b[i];
 (*p1).next = a[2];
         @addrp0
                 а
                                         @addr1
  рО
           b
                 0
                                                       Mem1
                                                 ?2
                                           а
          next
                                          b
            (addr1
  p1
                                          next
                                              @addr5
                                                         Mem$
                                                а
                                               b
                                               next
                                  addr5
b[0]
                      a[0]
                                              @addr6
                                                         Mem 6
                                  (addr6)
b[1]
                       a[1]
                                                а
                                  addr7
b[2]
                      a[2]
                                                b
                                  addr8
b[3]
                      a[3]
                                               next
b[4]
                      a[4]
                                              @addr7
                                                         Mem 7
                            @addr8
                                      Mem8
                                                а
             3
i
                                    3
                             а
                                                b
                             b
                                               next
                            next
```

```
for (i = 1; i < 4; i++)
 {
    a[i] = (struct T*) malloc(sizeof(struct T));
    (*a[i]).next = a[i-1];
    (*a[i]).a = i;
    b[i] = &a[i];
    (**b[i]).next = *b[i];
                                     we continue .
 (*p1).next = a[2];
         @addrp0
                 а
                                         @addr1
           b
                 0
  рO
                                                       Mem1
                                                 ?2
                                          а
          next
                                          b
            (addr1
  p1
                                         next
                                              @addr5
                                                        Mem 5
                                               а
                                               b
                                              next
                                  addr5
b[0]
                      a[0]
                                              @addr6
                                                         Mem 6
                                  (addr6
b[1]
                       a[1]
                                                а
                                  addr7
b[2]
                      a[2]
                                               b
                                  addr8
b[3]
                      a[3]
                                               next
                      a[4]
b[4]
                                              @addr7
                                                         Mem 7
                           @addr8
                                      Mem8
                                                а
             3
i
                             а
                                                b
                             b
                                               next
                            next
```

```
cursor = a[0];
for (j = 0; j < 5; j++)
{
          cursor = (*cursor).next;
}</pre>
```



```
cursor = a[0];
 for (j = 0; j < 5; j++)
 {
          cursor = (*cursor).next;
 }
  j
                             cursor
         @addrp0
                  0
            а
                                          @addr1
                  0
           b
  рO
                                                         Mem1
                                                  (?2)
                                            а
          next
                                            b
             (addr1
  р1
                                           next
                                               @addr5
                                                          Mem$
                                                 а
                                                 b
                                                next
                                   addr5
b[0]
                       a[0]
                                               @addr6
                                                           Mem 6
                                   addr6
b[1]
                       a[1]
                                   addr7
b[2]
                       a[2]
                                                 b
                                   addr8
b[3]
                       a[3]
                                                next
b[4]
                       a[4]
                                               @addr7
                                                           Mem 7
                            @addr8
                                       Mem8
              3
 i
                              а
                                                 b
                              b
                                                next
                             next
```

```
cursor = a[0];
 for (j = 0; j < 5; j++)
 {
          cursor = (*cursor).next;
 }
  j
                             cursor
         @addrp0
                  0
            а
                                          @addr1
                  0
           b
  рO
                                                         Mem1
                                                  ?2
                                            а
          next
                                           b
             (addr1
  p1
                                           next
                                               @addr5
                                                          Mem$
                                                 а
                                                b
                                                next
                                   addr5
b[0]
                       a[0]
                                               @addr6
                                                           Mem 6
                                   addr6
b[1]
                       a[1]
                                   addr7
b[2]
                       a[2]
                                                 b
                                   addr8
b[3]
                       a[3]
                                                next
b[4]
                       a[4]
                                               @addr7
                                                           Mem 7
                            @addr8
                                       Mem8
              3
 i
                              а
                                                 b
                              b
                                                next
                             next
```

```
cursor = a[0];
 for
            <mark>0</mark>; j < 5; j++)
      (j = 
 {
           cursor = (*cursor).next;
 }
  j
                              cursor
          @addrp0
                   0
            а
                                             @addr1
                   0
            b
  рO
                                                            Mem1
                                                     ?2
                                              а
           next
                                              b
              (addr1
  p1
                                             next
                                                  @addr5
                                                              Mem$
                                                    а
                                                    b
                                                   next
                                     addr5
b[0]
                         a[0]
                                                  @addr6
                                                              Mem 6
                                     addr6
b[1]
                         a[1]
                                     addr7
b[2]
                        a[2]
                                                    b
                                     addr8
                         a[3]
b[3]
                                                   next
                         a[4]
b[4]
                                                  @addr7
                                                              Mem 7
                              @addr8
                                         Mem8
              3
 i
                                а
                                                    b
                                b
                                                   next
                               next
```

```
cursor = a[0];
 for
            <mark>0</mark>; j < 5; j++)
      (j
 {
           cursor = (*cursor).next;
 }
                 0
  j
                              cursor
          @addrp0
                   0
            а
                                             @addr1
                   0
            b
  рO
                                                            Mem1
                                                     ?2
                                              а
           next
                                              b
              addr1
  p1
                                             next
                                                  @addr5
                                                              Mem$
                      (*cursor).next
                                                    а
                                                    b
                                                   next
                                     addr5
b[0]
                         a[0]
                                                  @addr6
                                                              Mem 6
                                     (addr6
b[1]
                         a[1]
                                                    а
                                     addr7
b[2]
                        a[2]
                                                    b
                                     addr8
                         a[3]
b[3]
                                                   next
                         a[4]
b[4]
                                                  @addr7
                                                              Mem 7
                              @addr8
                                          Mem8
              3
 i
                                а
                                                    b
                                b
                                                   next
                               next
```

```
cursor = a[0];
 for
            <mark>0</mark>; j < 5; j++)
      (j
 {
                      (*cursor).next;
           cursor
 }
                 0
  j
                               cursor
          @addrp0
                   0
            а
                                             @addr1
                   0
            b
  рO
                                                            Mem1
                                                     ?2
                                               а
           next
                                              b
              addr1
  p1
                                              next
                                                  @addr5
                                                              Mem5
                       (*cursor).next
                                                    а
                                                    b
                                                   next
                                     addr5
b[0]
                         a[0]
                                                  @addr6
                                                              Mem 6
                                      (addr6
b[1]
                         a[1]
                                                    а
                                     addr7
b[2]
                         a[2]
                                                    b
                                      addr8
                         a[3]
b[3]
                                                   next
b[4]
                         a[4]
                                                  @addr7
                                                              Mem 7
                              @addr8
                                          Mem8
               3
 i
                                а
                                                    b
                                b
                                                   next
                               next
```

```
cursor = a[0];
 for
            <mark>0</mark>; j < 5; j++)
      (j
 {
           cursor = (*cursor).next;
 }
                 0
  j
                               cursor
          @addrp0
                   0
            а
                                             @addr1
                   0
            b
  рO
                                                             Mem1
                                                      ?2
                                               а
           next
                                               b
              addr1
  p1
                                              next
                                                   @addr5
                                                               Merh $
                                                     а
                                                     b
                                                    next
                                      addr5
b[0]
                         a[0]
                                                   @addr6
                                                               Mem 6
                                      addr6
b[1]
                         a[1]
                                                     а
                                      addr7
b[2]
                         a[2]
                                                     b
                                      addr8
                         a[3]
b[3]
                                                    next
                         a[4]
b[4]
                                                   @addr7
                                                               Mem 7
                               @addr8
                                          Mem8
               3
 i
                                 а
                                                     b
                                b
                                                    next
                               next
```

```
cursor = a[0];
 for
      (j = 1; j < 5; j++)
 {
          cursor = (*cursor).next;
 }
  j
                             cursor
         @addrp0
                  0
            а
                                           @addr1
                  0
           b
  рO
                                                         Mem1
                                                   ?2
                                            а
           next
                                            b
             (addr1
  p1
                                           next
                                               @addr5
                                                           Mem$
                                                 а
                                                 b
                                                next
                                   addr5
b[0]
                       a[0]
                                                @addr6
                                                           Mem 6
                                    addr6
b[1]
                        a[1]
                                   addr7
b[2]
                       a[2]
                                                 b
                                    addr8
                       a[3]
b[3]
                                                 next
                       a[4]
b[4]
                                                @addr7
                                                           Mem 7
                             @addr8
                                       Mem8
              3
 i
                              а
                                                 b
                              b
                                                 next
                             next
```

```
cursor = a[0];
 for
           1; j < 5; j++)
      (j
 {
          cursor = (*cursor).next;
 }
                1
  j
                             cursor
         @addrp0
                  0
            а
                                           @addr1
                  0
            b
  рO
                                                         Mem1
                                                   ?2
                                            а
           next
                                            b
              addr1
  p1
                                           next
                                                @addr5
                                                           Mem
                                                  а
                                                 b
                                                 next
                                    addr5
b[0]
                       a[0]
                                                @addr6
                                                           Mem
                                    addr6
b[1]
                        a[1]
                                                  а
                                    addr7
b[2]
                       a[2]
                                                  b
                                    addr8
                       a[3]
b[3]
                                                 next
                       a[4]
b[4]
                                                @addr7
                                                           Mem
                             @addr8
                                        Mem8
              3
 i
                               а
                                                  b
                              b
                                                 next
                             next
```

```
cursor = a[0];
 for
            2; j < 5; j++)</pre>
      (j
 {
          cursor = (*cursor).next;
 }
  j
                              cursor
          @addrp0
                  0
            а
                                            @addr1
                  0
            b
  рO
                                                           Mem1
                                                    (?2)
                                             а
           next
                                             b
             (addr1
  p1
                                            next
                                                 @addr5
                                                            Mem
                                                   а
                                                  b
                                                  next
                                    addr5
b[0]
                        a[0]
                                                 @addr6
                                                             Mem
                                    (addr6)
b[1]
                        a[1]
                                    addr7
b[2]
                        a[2]
                                                   b
                                    addr8
                        a[3]
b[3]
                                                  next
b[4]
                        a[4]
                                                 @addr7
                                                             Mem
                             @addr8
                                        Mem8
              3
 i
                               а
                                                   b
                               b
                                                  next
                              next
```

```
cursor = a[0];
 for
            2; j < 5; j++)</pre>
      (j
                                         cursor unchanged
 {
          cursor =
                     (*cursor).next;
 }
                2
  j
                              cursor
          @addrp0
                  0
            а
                                           @addr1
                  0
            b
  рO
                                                          Mem1
                                                    (?2)
                                             а
           next
                                             b
              addr1
  p1
                                            next
                                                @addr5
                                                            Mem
                                                  а
                                                  b
                                                 next
                                    addr5
b[0]
                        a[0]
                                                 @addr6
                                                            Mem
                                    (addr6)
b[1]
                        a[1]
                                    addr7
b[2]
                        a[2]
                                                  b
                                    addr8
                        a[3]
b[3]
                                                 next
b[4]
                        a[4]
                                                 @addr7
                                                            Mem
                             @addr8
                                        Mem8
              3
 i
                               а
                                                  b
                               b
                                                 next
                              next
```

```
cursor = a[0];
 for
            <mark>3</mark>; j < 5; j++)
      (j
 {
           cursor = (*cursor).next;
 }
  j
                              cursor
          @addrp0
                   0
            а
                                             @addr1
                   0
            b
  рO
                                                            Mem1
                                                     (?2)
                                              а
           next
                                              b
              (addr1
  p1
                                             next
                                                  @addr5
                                                              Mem
                                                    а
                                                    b
                                                   next
                                     addr5
b[0]
                         a[0]
                                                  @addr6
                                                              Mem
                                     (addr6)
b[1]
                         a[1]
                                     addr7
b[2]
                        a[2]
                                                    b
                                     addr8
                         a[3]
b[3]
                                                   next
b[4]
                         a[4]
                                                  @addr7
                                                              Mem
                              @addr8
                                         Mem8
              3
 i
                                а
                                                    b
                                b
                                                   next
                               next
```

```
cursor = a[0];
 for
            <mark>3</mark>; j < 5; j++)
      (j
                                          cursor unchanged
 {
           cursor =
                      (*cursor).next;
 }
                3
  j
                              cursor
          @addrp0
                   0
            а
                                            @addr1
                   0
            b
  рO
                                                            Mem1
                                                     (?2)
                                              а
           next
                                              b
              addr1
  p1
                                             next
                                                 @addr5
                                                             Mem
                                                   а
                                                   b
                                                  next
                                     addr5
b[0]
                        a[0]
                                                  @addr6
                                                              Mem
                                     (addr6)
b[1]
                         a[1]
                                     addr7
b[2]
                        a[2]
                                                   b
                                     addr8
                        a[3]
b[3]
                                                   next
b[4]
                        a[4]
                                                  @addr7
                                                              Mem
                              @addr8
                                         Mem8
              3
 i
                                а
                                                    b
                                b
                                                   next
                               next
```