Programming in C

Dr. Neill Campbell
Neill.Campbell@bristol.ac.uk

University of Bristol

October 8, 2021

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Call-by-Value

```c
#include <stdio.h>

void changex(int x);

int main(void)
{
   int x = 1;

   changex(x);
   printf("%i\n", x);
   return 0;
}

void changex(int x)
{
   x = x + 1;
}
```

Execution :

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- In the program, the function cannot change the value of `x` as defined in `main()` since a **copy** is made of it.

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void changex(int x);

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Execution :

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- In the program, the function cannot change the value of `v` as defined in `main()` since a **copy** is made of it.
- To allow a function to modify the value of a variable passed to it we need a mechanism known as **call-by-reference**, which uses the **address** of variables (pointers).

Call-by-Reference

- We have already seen addresses used with `scanf()`. The function call:

  ```
  scanf("%i", &v);
  ```

  causes the appropriate value to be stored at a particular address in memory.

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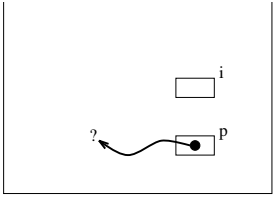

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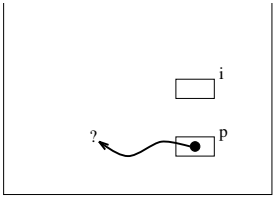
- Here `i` is an `int` and `p` is of type *pointer to int*.



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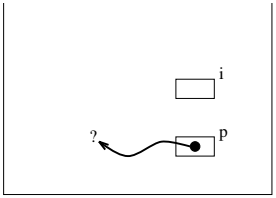
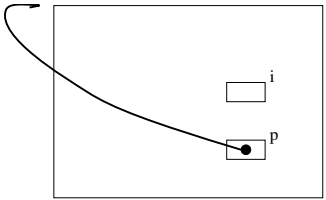
- `int i, *p;`
- Here `i` is an `int` and `p` is of type *pointer to int*.
- Pointers have a legal range which includes the special address 0 and a set of positive integers which are the machine addresses of a particular system.



The *NULL* Pointer

- `p = NULL;`



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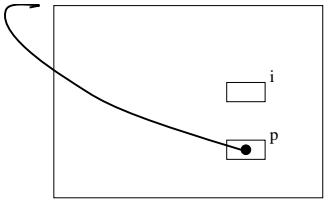

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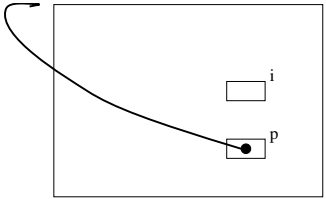
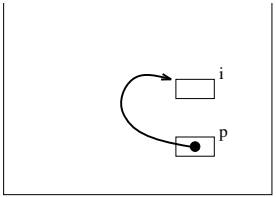
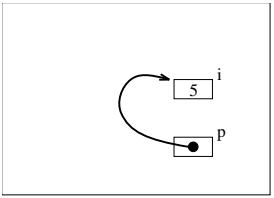


- `p = &i;`



Equivalence of *i* and **p*

- `i = 5;`



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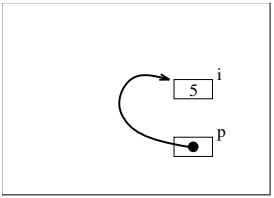

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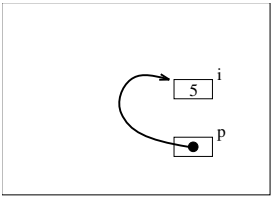


```c
#include <stdio.h>

int main(void)
{

    int i = 5;
    int* p = &i;
    printf("%i\n", *p);
    i = 17;
    printf("%i\n", *p);
    *p = 99;
    printf("%i\n", i);

    return 0;

}
```

Execution :

```
5
17
99
```

scanf Again

```c
#include <stdio.h>

int main(void)
{

    int i;
    int* p;

    p = &i;
    printf("Please Type a number : ");
    scanf("%i", &i);
    printf("%i\n", i);
    printf("Please Type a number : ");
    scanf("%i", p);
    printf("%i\n", i);

    return 0;

}
```

Execution :

```
Please Type a number : 70
70
Please Type a number : 3
3
```

scanf Again

```c
#include <stdio.h>

int main(void)
{

    int i;
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    p = &i;
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    scanf("%i", &i);
    printf("%i\n", i);
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    printf("%i\n", i);

    return 0;

}
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Please Type a number : 70
70
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- In many ways the dereference operator $*$ is the inverse of the address operator $\&$.

```c
float x = 5, y = 8, *p;
p = &x;
y = *p;
```

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int main(void)
{

    int i;
    int* p;

    p = &i;
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    scanf("%i", &i);
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```c
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- What is this equivalent to ?

The *swap* Function

```c
#include <stdio.h>

void swap(int* p, int* q);

int main(void)
{
   int   a = 3, b = 7;

   // 3 7 printed
   printf("%i %i\n", a, b);
   swap(&a, &b);
   // 7 3 printed
   printf("%i %i\n", a, b);
   return 0;
}

void swap(int* p, int* q)
{
   int   tmp;

   tmp = *p;
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}
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Execution :

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3 7
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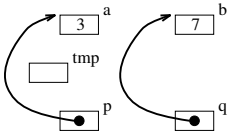

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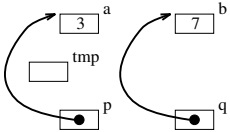

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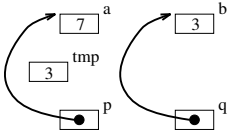

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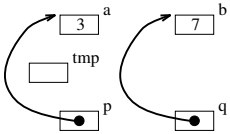

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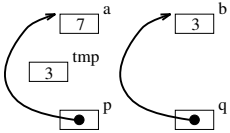
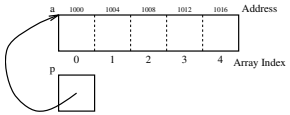


- Remeber that the variables *a* and *b* are not in the scope of *swap()*.

Arrays are Pointers ?

- An array name by itself is simply an address (**Array Decay**).



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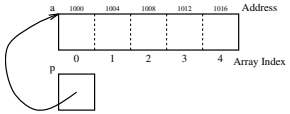
  declares an array of 5 elements, and a is the address of the start of the array.



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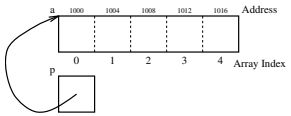

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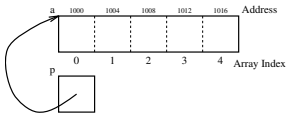

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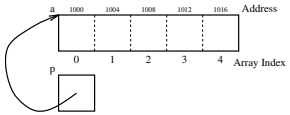

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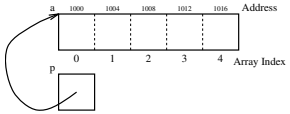

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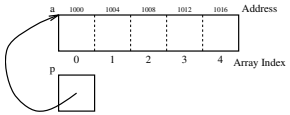

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  `p = a + 1;`
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- Notice that `p = a + 1` advances the pointer **4** bytes and not 1 byte. This is because an integer is 4 bytes long and `p` is a pointer to an int.
- we can use the pointer `p` is exactly the same way as normal, i.e.:

  `*p = 5;`

Summing an Array

```c
#include <stdio.h>

#define NUM 5

int sum(int a[]);

int main(void)
{

    int n[NUM] = {10, 12, 6, 7, 2};

    printf("%i\n", sum(n));
    return 0;
}

int sum(int a[])
{
    int sum = 0;

    for(int i=0; i<NUM; i++){
       sum += a[i];
    }
    return sum;
}
```

Execution :

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int sum(int* p );

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    int n[NUM] = {10, 12, 6, 7, 2};

    printf("%i\n", sum(n));
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}

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{
    int sum = 0;

    for(int i=0; i<NUM; i++){
       sum += *p;
       p++;
    }
    return sum;
}
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Pointers to Structures

- By default, structures are passed by value (copied) when used as a parameter to a function.

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- But, like any other type, we could pass a pointer instead.
- The complication is that to access the elements of a structure via a pointer, we use the "->" operator, and not the ".".

```
void print_deck(card d[DECK], int n)
{
   char str[BIGSTR];
   for(int i=0; i<n; i++){
      print_card(str, &d[i]);
      printf("%s\n", str);
   }
   printf("\n");
}

#define SMALLSTR 20
void print_card(char s[], const card* p)
{
   // Note the +1 below : zero pips not used, but makes easier coding ?
   char pipnames[PERSUIT+1][SMALLSTR] = {"Zero", "One", "Two", "Three",
                                         "Four", "Five", "Six", "Seven",
                                         "Eight", "Nine", "Ten", "Jack",
                                         "Queen", "King"};
   char suitnames[SUITS][SMALLSTR] = {"Hearts", "Diamonds", "Spades", "Clubs"};
   sprintf(s, "%s of %s", pipnames[p->pips], suitnames[p->st]);
}
```

Nested Structures

```c
#include <stdio.h>

struct dateofbirth {
   unsigned char day;
   unsigned short month;
   unsigned short year;
};
typedef struct dateofbirth dob;

typedef struct {
   char* name;
   dob date;
} person;

void print_byval(person b);
void print_byref(const person* p);

int main(void)
{
   person a = {"Gary", {17, 5, 1999}};
   print_byval(a);
   print_byref(&a);
}

void print_byval(person b)
{
   printf("%s %hhu/%hi/%hi\n", b.name, b.date.day, b.date.month, b.date.year);
}

void print_byref(const person* p)
{
   printf("%s %hhu/%hi/%hi\n", p->name, p->date.day, p->date.month, p->date.year);
}
```

Execution :

```
Gary 17/5/1999
Gary 17/5/1999
```

Table of Contents

K : Pointers

L : Advanced Memory Handling

String Constants

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int main(void)
{

    nify("neill");
    return 0;

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// In-Place : Swaps all 'n' -> 'N'
void nify(char* s)
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- It turns out that in `main()` we have passed a **constant** string to the function. This is in a part of memory that we have read-only permission.

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char* nify(char* s);

int main(void)
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- The string t is local to nify().
- What happens in this memory when outside the scope of this function is completely undefined.

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- The pointers s1 and s2 are the same.

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3  #include <assert.h>
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5
6  int main(void)
7  {
8
9     char* s1 = nify("inconveniencing");
10    char* s2 = nify("neill");
11    assert(strcmp(s2, "Neill")==0);
12    assert(strcmp(s1, "iNcoNveNieNciNg")==0);
13    free(s1);
14    free(s2);
15    return 0;
16
17 }
18
19 // malloc : Swaps all 'n' -> 'N'
20 char* nify(char* s)
21 {
22    int l = strlen(s);
23    char* t  = (char*)malloc(l+1);
24    if(t==NULL){
25       exit( EXIT_FAILURE );
26    }
27    strcpy(t, s);
28    for(int i=0; t[i]; i++){
29       if(t[i] == 'n'){
30          t[i] = 'N';
31       }
32    }
33    return t;
34 }
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Variable Length Arrays

```c
// This code is not allowed by the -Wvla flag
#include <stdio.h>
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#include <string.h>
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#define WORD 500

int main(void)
{

    char s[WORD] = "String";
    int n = strlen(s) + 1;
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- None of these is a problem if we use `malloc()`.

Memory Leaks

```c
// This leaks - but it's not obvious
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <assert.h>

#define WORD 500

int main(void)
{

    char s[WORD] = "String";
    int n = strlen(s);
    /* malloc() returns a pointer to memory that
       you have access to. Note forcing cast. */
    char* t = (char*) malloc(n+1);
    // If no space, returns NULL
    assert(t != NULL);
    // Deep copy: character by character
    strcpy(t, s);
    printf("%s %s\n", s, t);
    return 0;
}
```

Memory Leaks

```c
// This leaks - but it's not obvious
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <assert.h>

#define WORD 500

int main(void)
{

    char s[WORD] = "String";
    int n = strlen(s);
    /* malloc() returns a pointer to memory that
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- This code appears to work correctly.

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- This code appears to work correctly.
- However, it actually **leaks**. The memory allocated was never free()'d.
- This is best found by running the program valgrind.

```
String String
==474==
==474== HEAP SUMMARY:
==474==     in use at exit: 7 bytes in 1 blocks
==474==   total heap usage: 2 allocs, 1 frees, 1,031 bytes allocated
==474==
==474== LEAK SUMMARY:
==474==    definitely lost: 7 bytes in 1 blocks
```

free()

```c
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#include <stdlib.h>
#include <string.h>
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#define WORD 500

int main(void)
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    strcpy(t, s);
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    /* All malloc'd memory must be freed
       to prevent memory leaks */
    free(t);
    return 0;
}
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    /* Deep copy: character by character */
    strcpy(t, s);
    printf("%s %s\n", s, t);
    /* All malloc'd memory must be freed
       to prevent memory leaks */
    free(t);
    return 0;
}
```

- This code is now correct.

```
String String
==475==
==475== HEAP SUMMARY:
==475==     in use at exit: 0 bytes in 0 blocks
==475==   total heap usage: 2 allocs, 2 frees, 1,031 bytes allocated
==475==
==475== All heap blocks were freed -- no leaks are possible
```

Structures with Self-Referential Pointers

```c
// Store a list of numbers
#include <stdio.h>
#include <stdlib.h>
#include <assert.h>

struct data {
   int num;
   struct data* next;
};
typedef struct data data;

int main(void)
{
   data c = {5 , NULL};
   data b = {17, &c};
   data a = {11, &b};

   // print first number
   printf("%i\n", a.num);
   data* p = &a;
   // Can also get to it via p
   printf("%i\n", p->num);
   // Pointer chasing : The Key concept
   p = p->next;
   // We're accessing b, without using it's name
   printf("%i\n", p->num);
   p = p->next;
   // And c
   printf("%i\n", p->num);

   return 0;
}
```

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- The structure contains a pointer to a something of it's own type (even before we've fully defined the struture itself).

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   // And c
   printf("%i\n", p->num);

   return 0;
}
```

- The structure contains a pointer to a something of it's own type (even before we've fully defined the struture itself).
- Here, if p points to a, then p->next->next point to c.

Linked Lists

```c
// Store a list of numbers (length unknown)
#include <stdio.h>
#include <stdlib.h>
#include <assert.h>

#define MAXNUM 20
#define ENDNUM 10

struct data {
   int num;
   struct data* next;
};
typedef struct data data;

void addtolist(data* tail);
void printlist(data* st);

int main(void)
{
   data *p, *start;
   start = p = calloc(1, sizeof(data));
   assert(p);
   p->num = rand()%MAXNUM;
   // Add other numbers to the list
   do{
      addtolist(p);
      p = p->next;
   }while(p->num != ENDNUM);
   printlist(start);
   // Need to free up list - not shown here ...
   return 0;
}
```

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#include <stdio.h>
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#define MAXNUM 20
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struct data {
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typedef struct data data;

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int main(void)
{
   data *p, *start;
   start = p = calloc(1, sizeof(data));
   assert(p);
   p->num = rand()%MAXNUM;
   // Add other numbers to the list
   do{
      addtolist(p);
      p = p->next;
   }while(p->num != ENDNUM);
   printlist(start);
   // Need to free up list - not shown here ...
   return 0;
}
```

```c
// Create some new space and store number in it
void addtolist(data* tail)
{
   tail->next = calloc(1, sizeof(data));
   assert(tail);
   tail->next->num = rand()%MAXNUM;
}

void printlist(data* st)
{
   while(st != NULL){
      printf("%i ", st->num);
      st = st->next;
   };
   printf("\n");
}
```

Execution :

```
3 6 17 15 13 15 6 12 9 1 2 7 10
```