# Pointers – Strings

## Basics of Programming 1


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# Content

Chapter 1

# Pointers

Fundamental Theorem of Software Engineering (FTSE)

*"We can solve any problem*
*by introducing an extra level of indirection."*
Andrew Koenig

# Where are the variables?

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Let's write a program that lists the address and value of variables

```
1 int a = 2;
2 double b = 8.0;
3 printf("address of a: %p, its value: %d\n", &a, a);
4 printf("address of b: %p, its value: %f\n", &b, b);
```

```
address of a:  0x7fffa3a4225c, its value:  2
address of b:  0x7fffa3a42250, its value:  8.000000
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```

- address of variable: starting address of "memory block" containing the variable, expressed in bytes
- with the address-of operator we can create address of any variables[1] like this `&<reference>`

[1] more precisely left-values

# The pointer type

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The pointer type is for storing memory addresses

## Declaration of pointer

```
<pointed type> * <identifier>;
```

```
1  int*    p;  /*   p stores the address of one int data */
2  double* q;  /*   q stores the address of one double data */
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it is the same, even if arranged in a different way

```
1  int    *p;  /*   p stores the address of one int data */
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- If pointer `p` stores the address of variable `a`, then `p` "points to `a`"
- If `p` points to `a`, then variable `a` can be accessed as `*p`. Here `*` is the operator of indirection (dereference operator).

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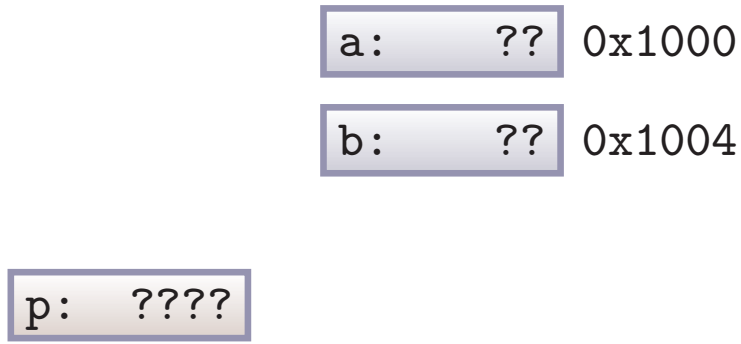

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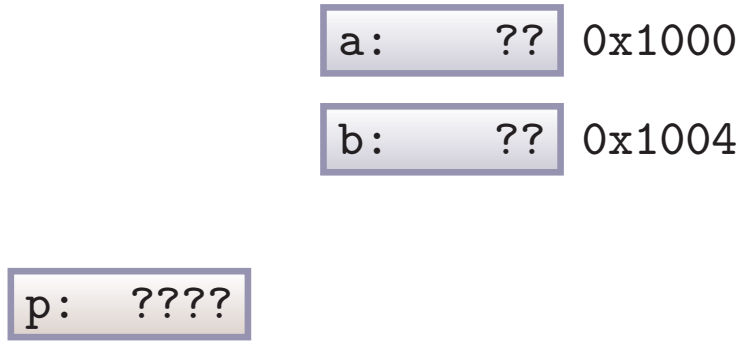

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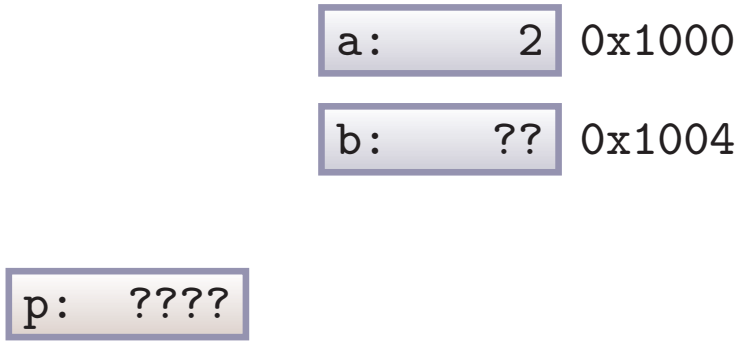

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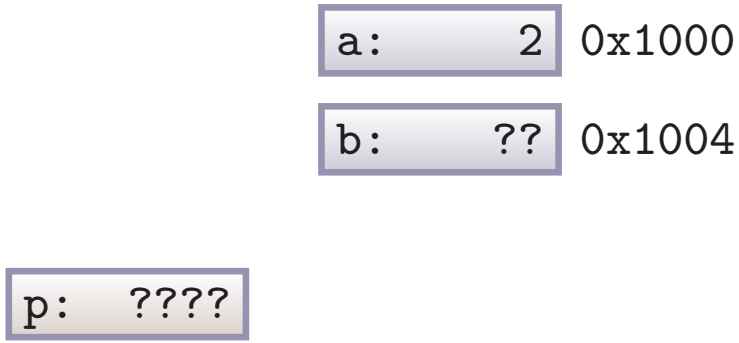

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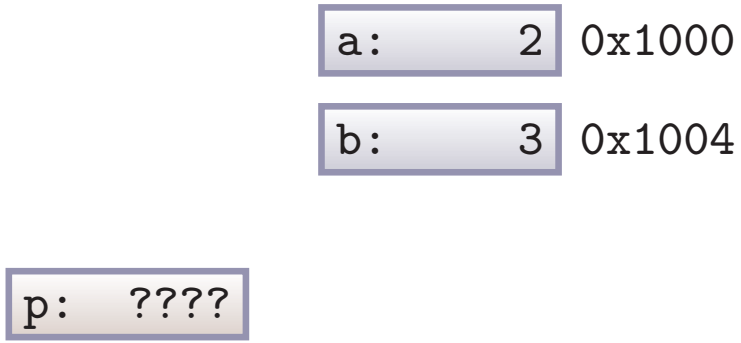

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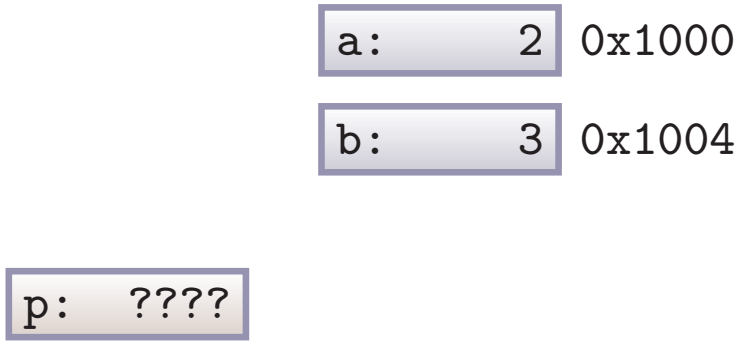

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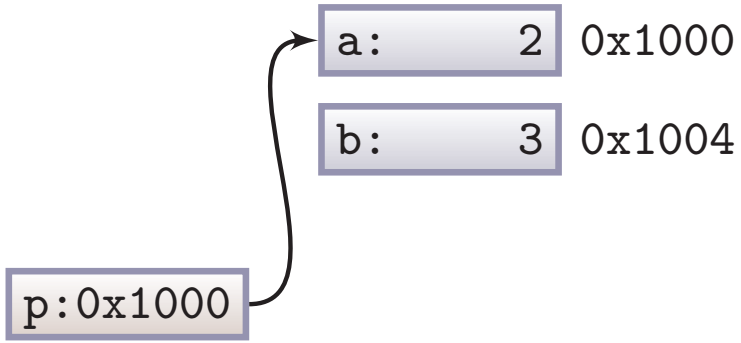

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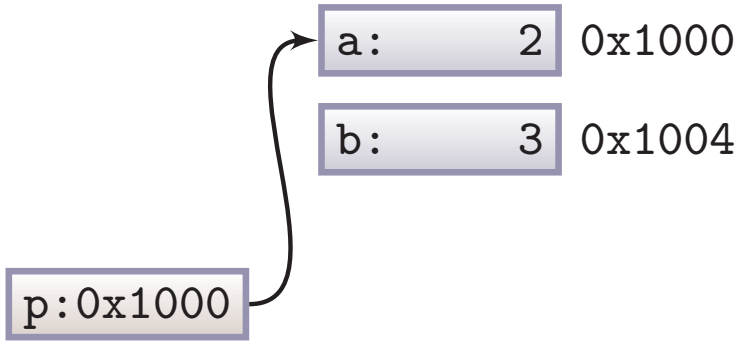

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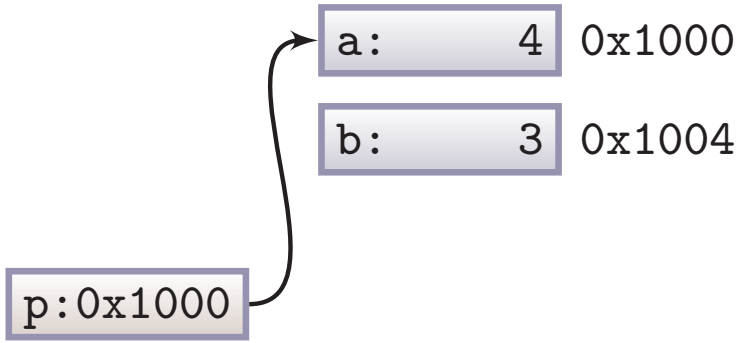

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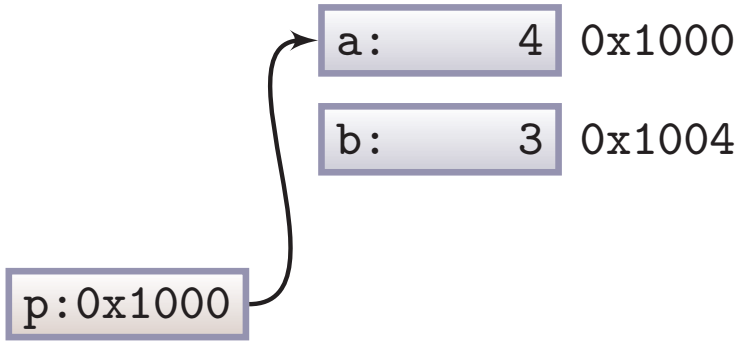

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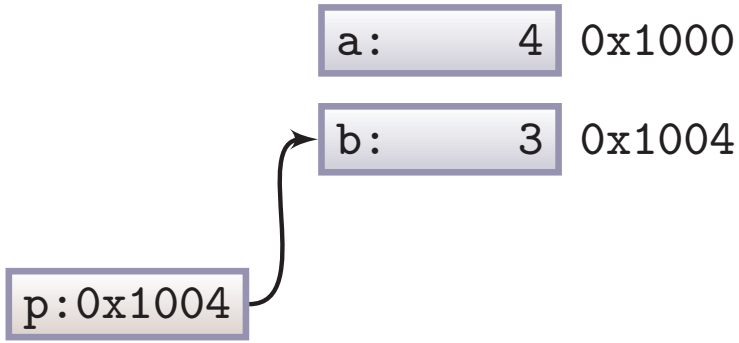

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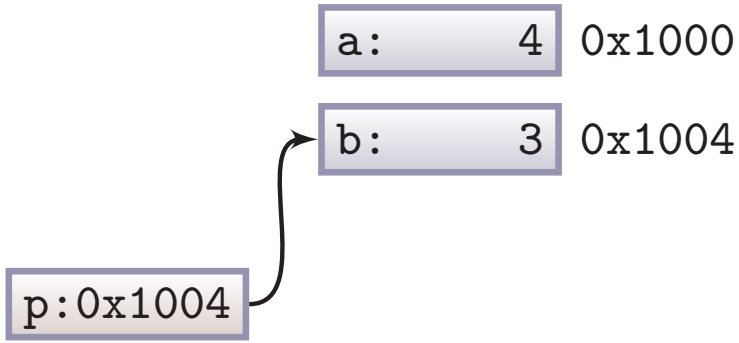

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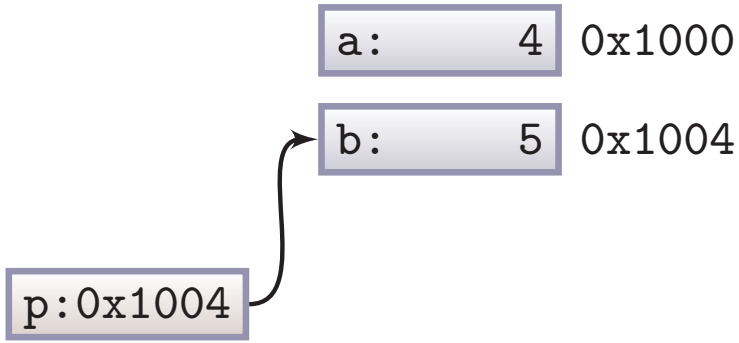

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- Interpreting declaration: type of *p is `int`

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1 int *p;       /* get used to this version */
```

- Multiple declaration: type of a, *p and *q is `int`

```
1 int a, *p, *q; /* at least because of this */
```

# Application – Function for exchanging two variables

DEPARTMENT OF NETWORKED SYSTEMS AND SERVICES

```
1  void xchg(int x, int y) {
2    int tmp = x;
3    x = y;
4    y = tmp;
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7  void xchgp(int *px, int *py) {
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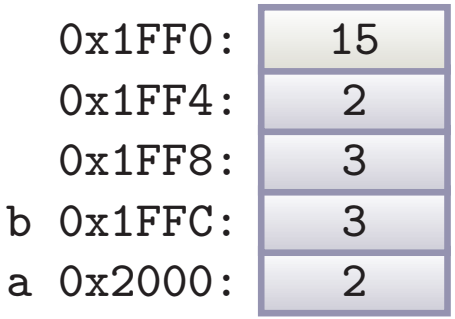

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| x | 0x1FF4: | 2 |
| y | 0x1FF8: | 3 |
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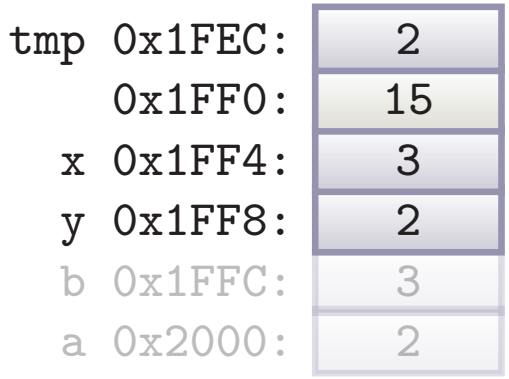

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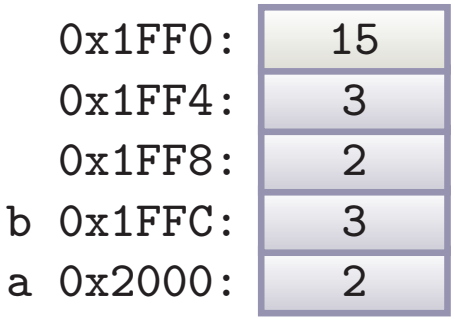

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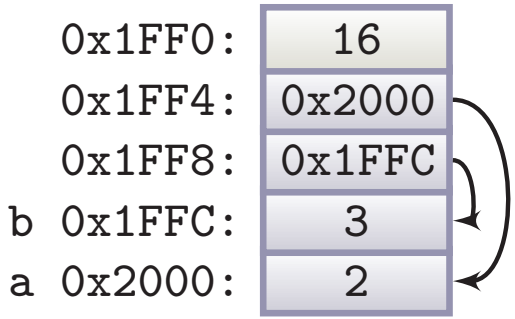

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DEPARTMENT OF NETWORKED SYSTEMS AND SERVICES

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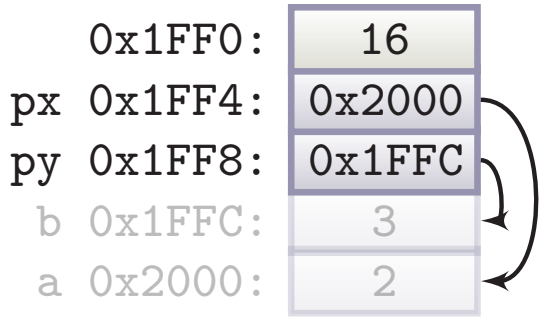

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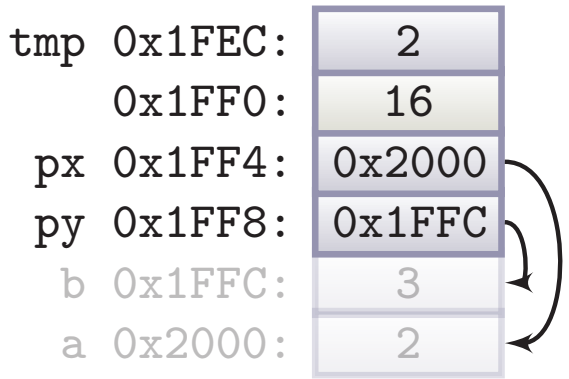

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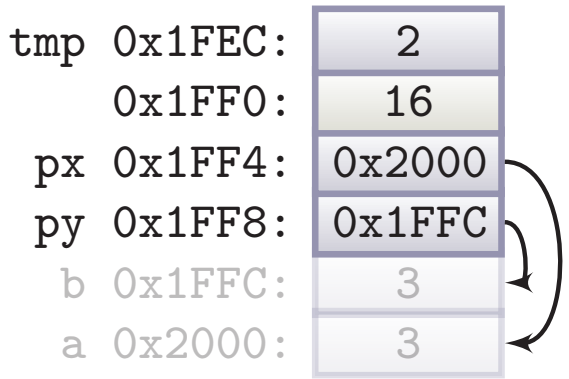

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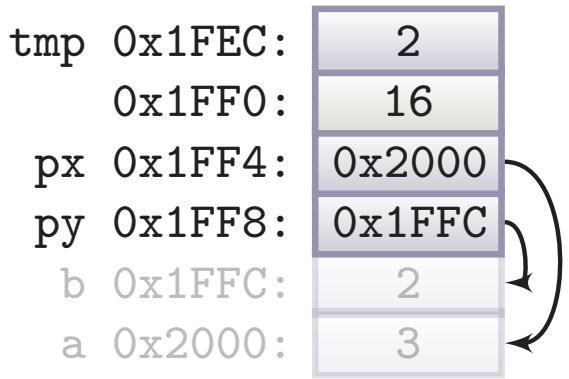

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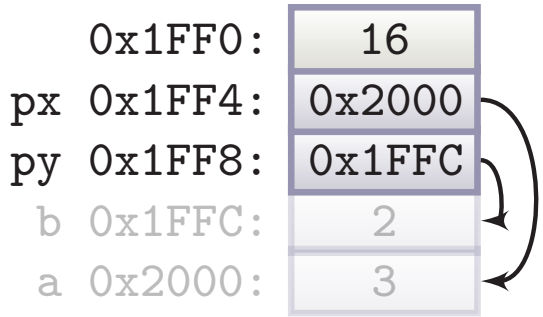

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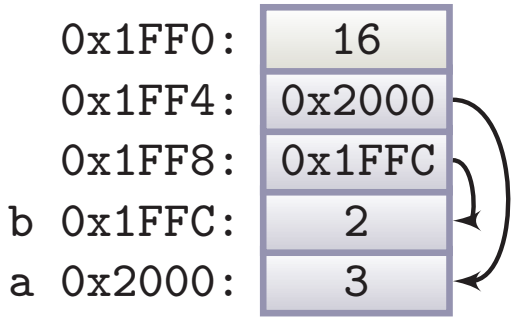

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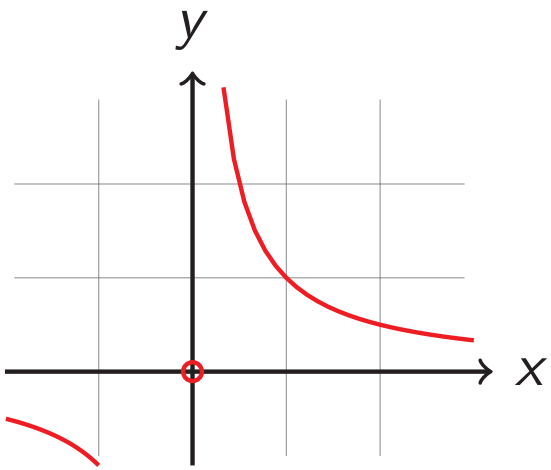
  Instead...

```
1  int inverse(double x, double *py)
2  {
3    if (abs(x) < 1e-10) return 0;
4    *py = 1.0 / x;
5    return 1;
6  }
```

link



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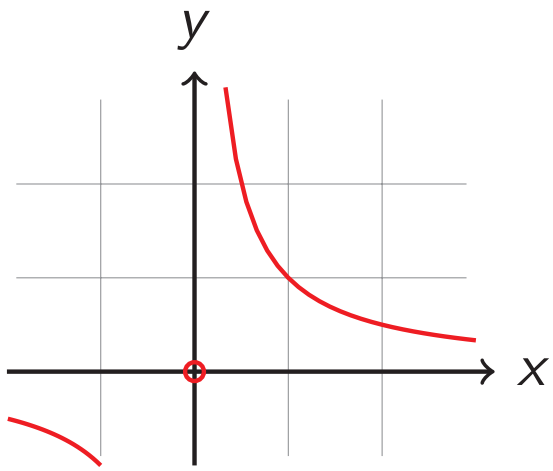


```c
double y;          /* memory allocation for result */
if (inverse(5.0, &y) == 1)
  printf("Reciprocal of %f is %f\n", 5.0, y);
else
  printf("Reciprocal does not exist");
```

link

# Application – return values as parameters



- Now we understand what this means

```
1 int n, p;
2 /* return value as parameter */
3 scanf("%d%d", &n, &p); /* we pass the addresses */
```

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- Other differences are detailed in pointer-arithmetics. . .

# Pointer-arithmetics



If `p` and `q` are pointers of the same type, then

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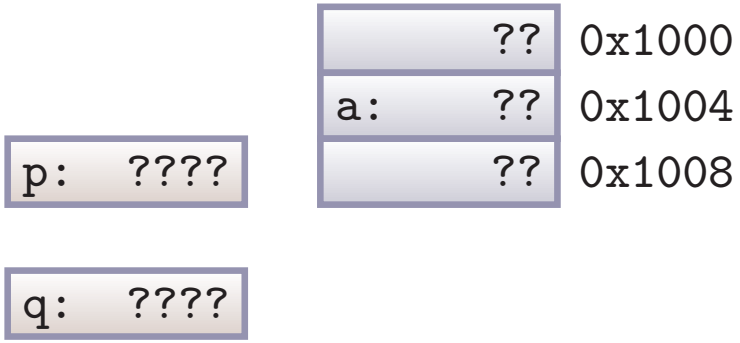


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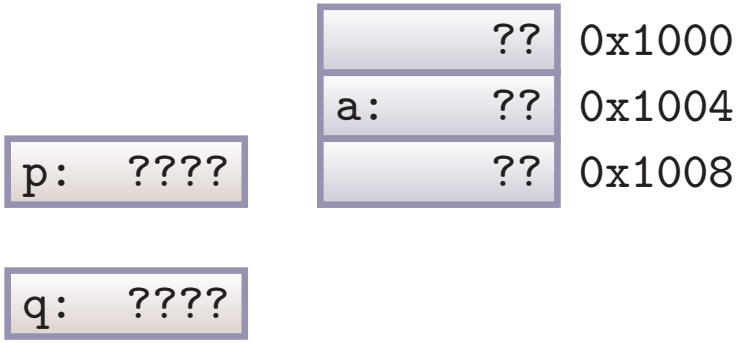


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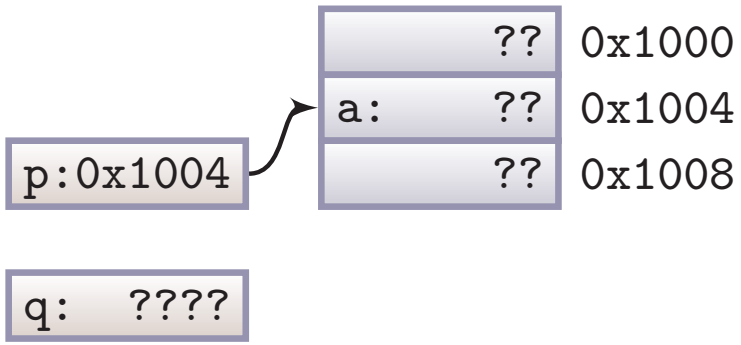


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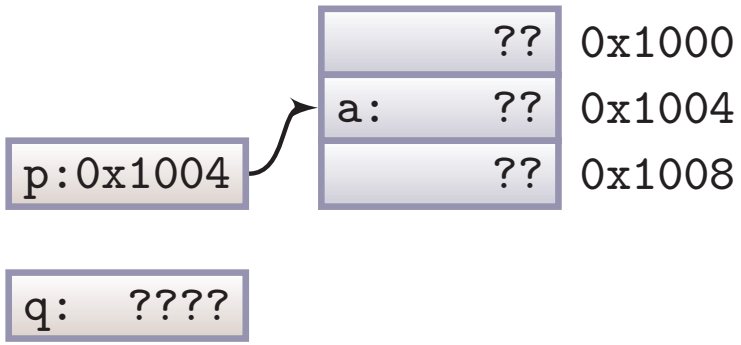


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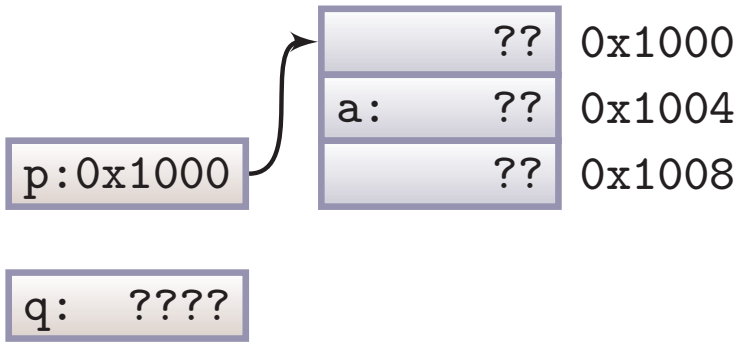


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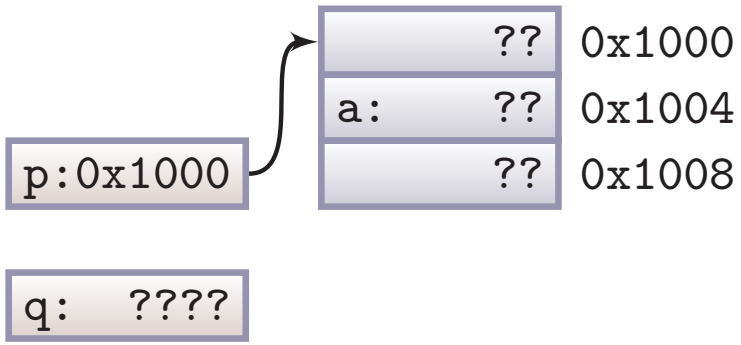


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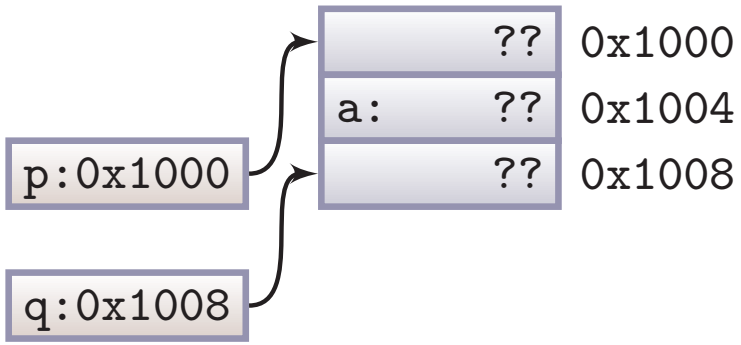


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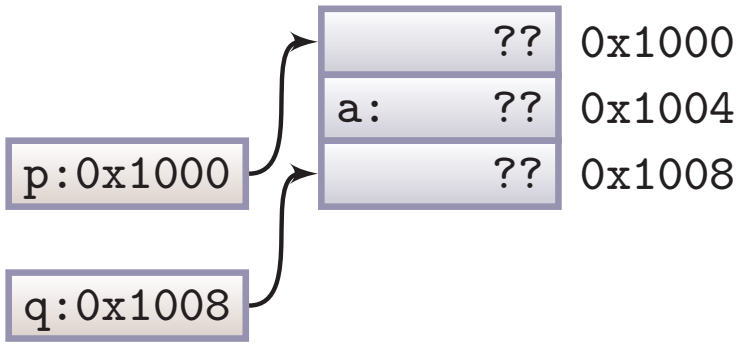


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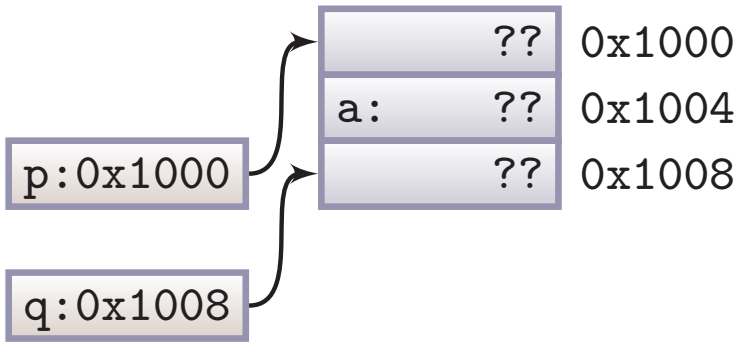


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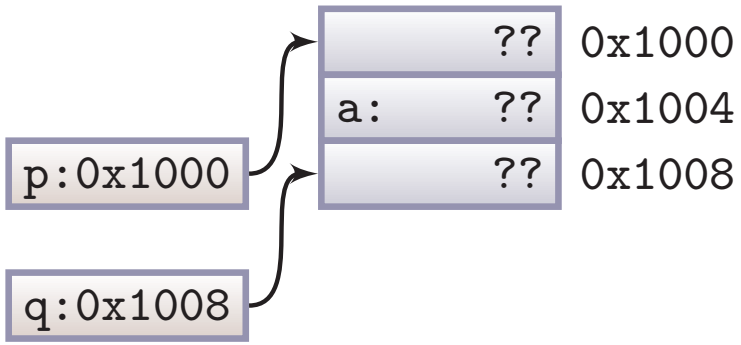


**2**

- At pointer-arithmetic operaitons addresses are "measured" in the representation size of the pointed type, and not in bytes.[2]

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# Pointer-arithmetic



- In the above example pointer-arithmetic is strange, as we don't know what is before or after variable a in the memory.
- This operation is meaningful, when we have variables of the same type, stored in the memory one afte the other.
- This is the case for arrays.

# Pointers and arrays

DEPARTMENT OF NETWORKED SYSTEMS AND SERVICES

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```
1  int t[5] = {1,4,2,7,3};
2  int *p, i;
3
4  p = &t[0];
5  for (i = 0; i < 5; ++i)
6    printf("%d ", *(p+i));
```

```
1 4 2 7 3
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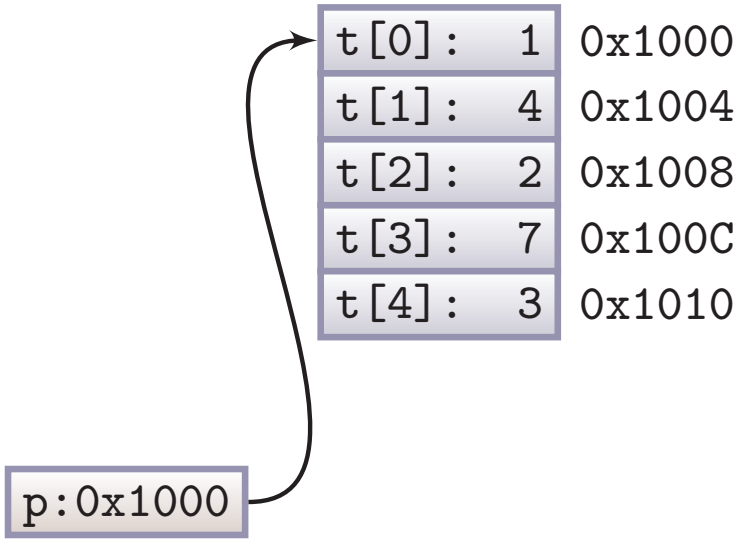

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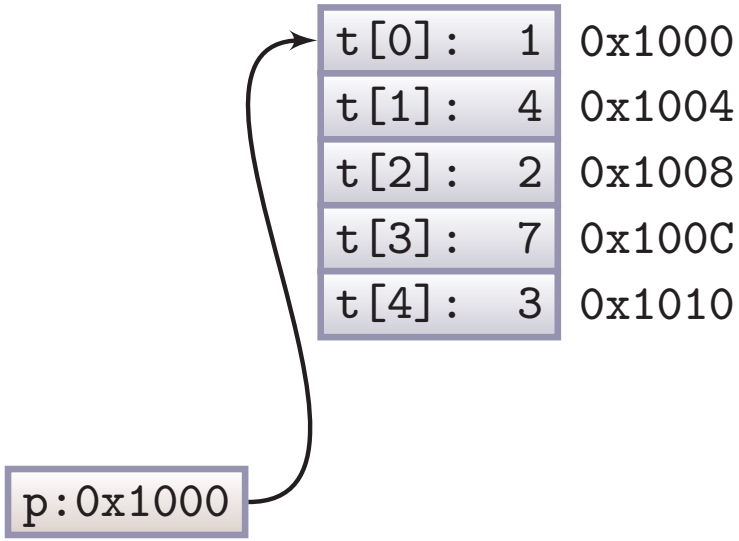


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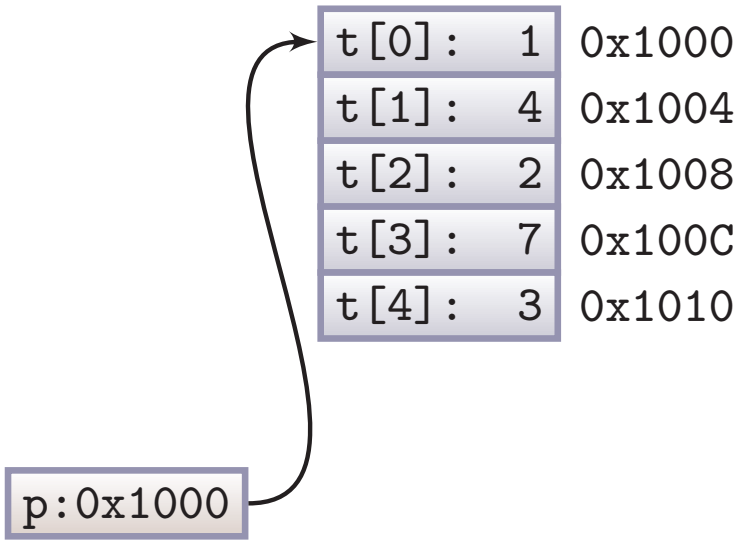

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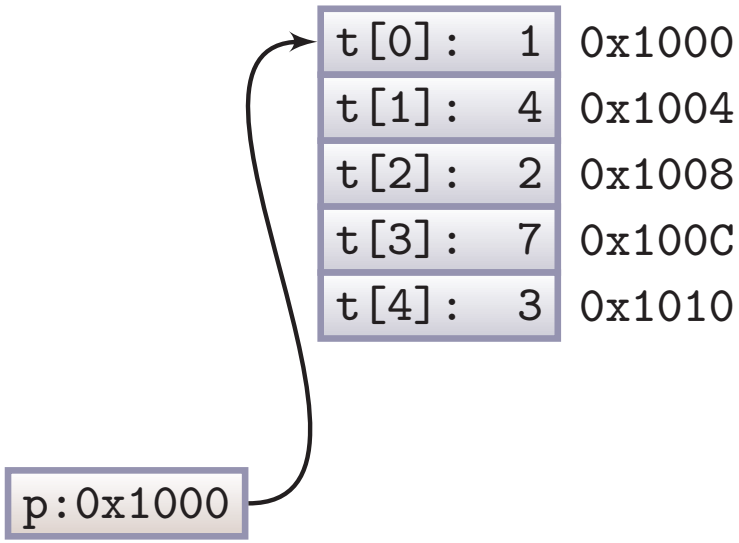


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# Pointers and arrays



- Arrays can be taken as pointers.
  The identifier (name) of array is the starting address of the array, in other words the value of expression `t` is `&t[0]`

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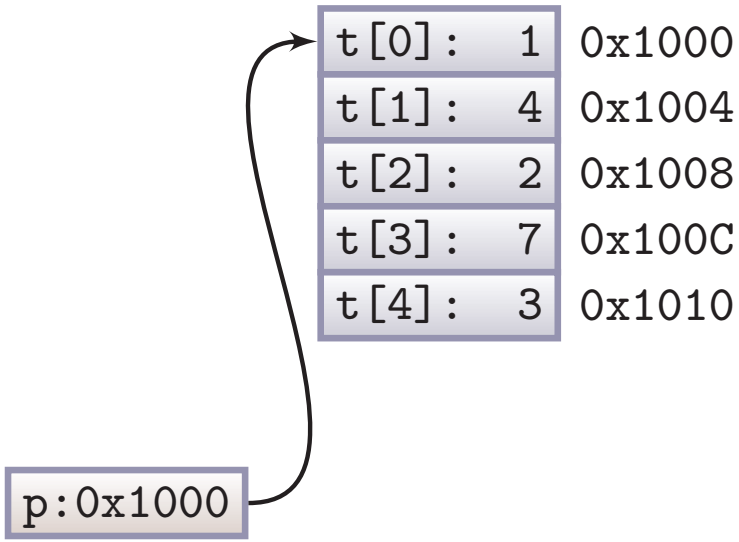
```
1  int t[5] = {1,4,2,7,3};
2  int *p, i;
3
4  p = t; /* &t[0] */
5  for (i = 0; i < 5; ++i)
6    printf("%d ", p[i]);
```

```
1 4 2 7 3
```



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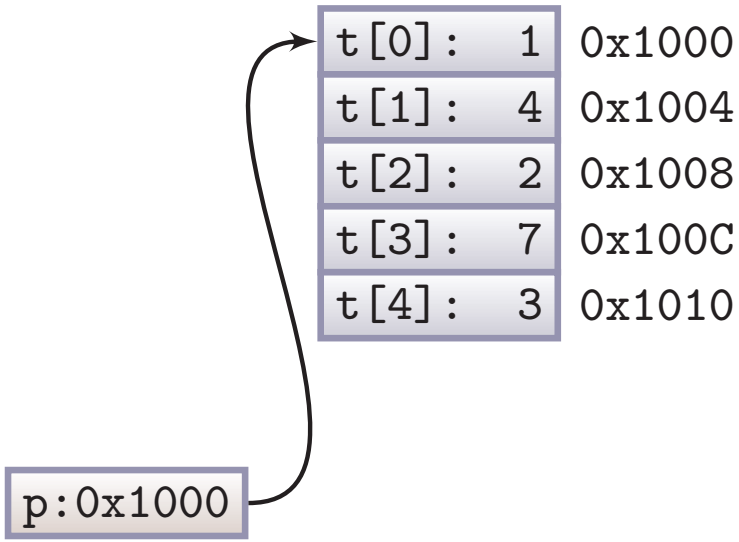


- Pointer-arithmetics work for arrays too:
  `t+i` is identical to `&t[i]`

# Pointers and arrays – summary



- Pointer can be taken as array, and array as a pointer.

# Pointers and arrays – summary

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  the compiler will always replace `a[i]` with `*(a+i)`,
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  - Elements of array have allocated space in memory (variables).
    No allocated elements belong to the pointer.
  - Starting address of array is constant, it cannot be changed.
    Pointer is a variable, the address stored in it can be modified.

```
1  int array[5] = {1, 3, 2, 4, 7};
2  int *p = array;
3
4  /* the elements can be accessed via p and a */
5  p[0] = 2;              array[0] = 2;
6  *p = 2;                *array = 2;
7
8  /* p can be changed   array CANNOT */
9  p = p+1; /* ok */      array = array + 1; /* ERROR */
```

# Passing arrays to functions

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- Let's use a function to determine the first negative element of `array`!

[3] defined in `stdio.h`

# Passing arrays to functions

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- Passing an array:
  - Address of first element `double*`
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# Passing arrays to functions



- Let's use a function to determine the first negative element of array!
- Passing an array:
  - Address of first element `double*`
  - Size of the array `typedef unsigned int size_t`[3]

```c
double first_negative(double *array, size_t size)
{
  size_t i;
  for (i = 0; i < size; ++i)  /* for each elems. */
    if (array[i] < 0.0)
      return array[i];

  return 0; /* all are non-negative */
}
```

link

```c
double myarray[3] = {3.0, 1.0, -2.0};
double neg = first_negative(myarray, 3);
```

link

[3] defined in `stdio.h`

# Passing arrays to functions



- To distinguish arrays and pointers in the parameter list, we can use the array-notation when passing an array.

```
1  double first_negative(double array[], size_t size)
2                  /*   (double *array,  size_t size)  */
3  {
4     ...
5  }
```

# Passing arrays to functions



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```
1 double first_negative(double array[], size_t size)
2                  /*   (double *array,  size_t size)  */
3 {
4    ...
5 }
```

- In the formal parameter list `double a[]` is identical to `double *a`.
- In the formal parameter list we can use only empty `[]`, and size should be passed as a separate parameter!

# Passing arrays to functions

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- Let's use a function to determine the first negative element of array!
- The return value should be the address of the element found.

```
1  double *first_negative(double *array, size_t size)
2  {
3    size_t i;
4    for (i = 0; i < size; ++i)  /* for each elems. */
5      if (array[i] < 0.0)
6        return &array[i];
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8    return NULL; /* all are non-negative */
9  }
```

link

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link

# Null pointer

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# Null pointer



- The null pointer (`NULL`)
  - It stores the `0x0000` address
  - Agreed that it "points to nowhere"

Chapter 2

# Strings

# Strings

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- In C, text is stored in character arrays with termination sign, called as strings.

# Strings



- In C, text is stored in character arrays with termination sign, called as strings.
- The termination sign is the character with 0 ASCII-code `'\0'`, the null-character.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 'S' | 'o' | 'm' | 'e' | ' ' | 't' | 'e' | 'x' | 't' | '\0' |

# Defining strings as character arrays

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- Definition of character array with initialization

```
1  char s[] = {'H', 'e', 'l', 'l', 'o', '\0'};
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1 char s[] = {'H', 'e', 'l', 'l', 'o', '\0'};
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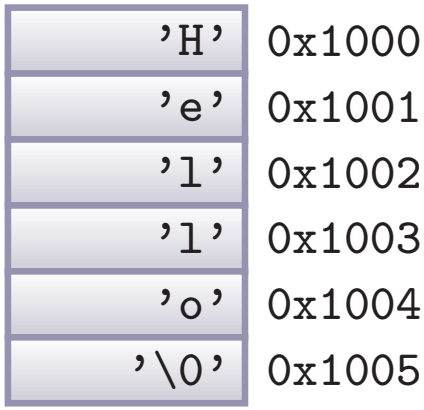
- The same in a more simple way

```
1 char s[] = "Hello"; /* s array (const.addr 0x1000) */
```



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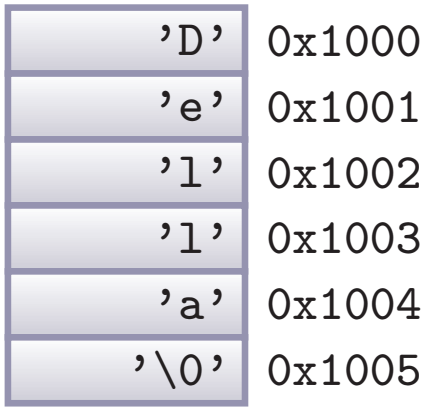



- Elements of s can be accessed with indexing or with pointer-arithmetics

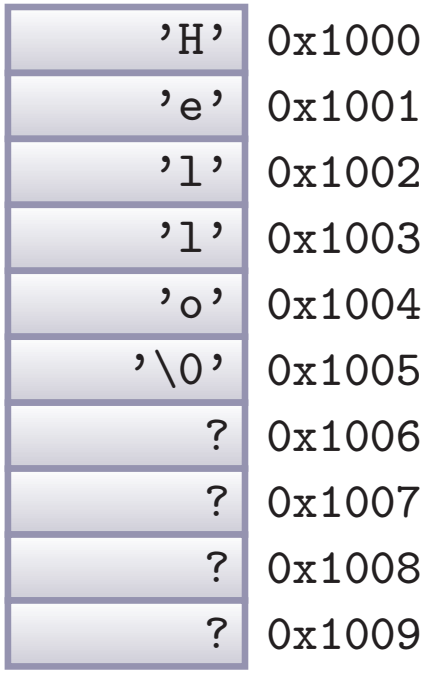
```
1 *s = 'D';    /* s is taken as pointer */
2 s[4] = 'a'; /* s is taken as array */
```

# Defining strings as character arrays



- We can allocate memory for a longer string than needed now, thus we have an overhead.

```
1  char s[10] = "Hello"; /* s array, (const.addr. 0x1000) */
```



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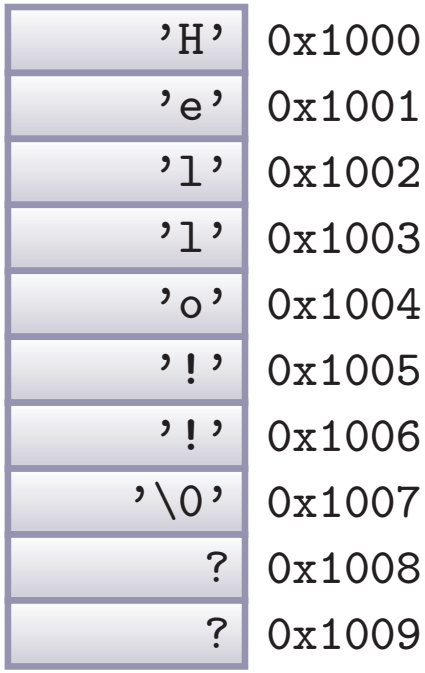



- Modification:

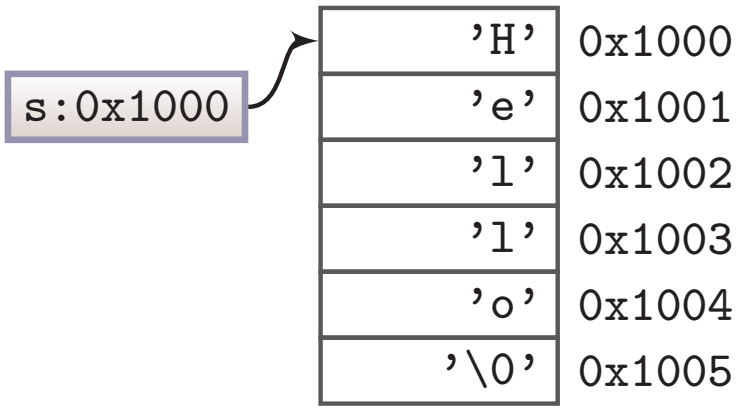
```c
s[5] = s[6] = '!';
s[7] = '\0';          /* must be terminated */
```

# Defining strings as character arrays



- Defining a constant character array and a pointer pointing to it, with initialization.

```
1  char *s = "Hello"; /* s pointer */
```



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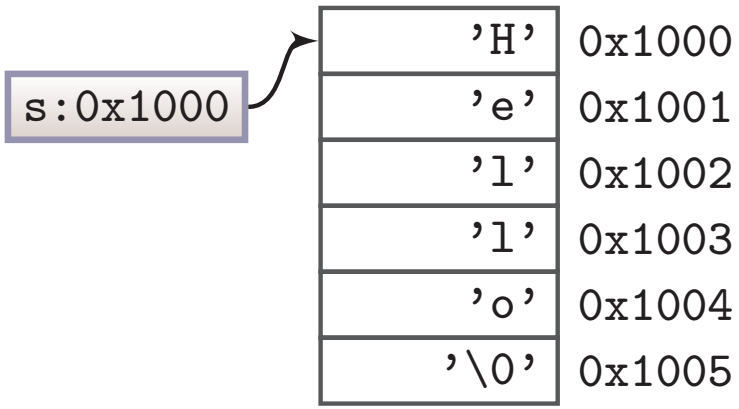


- Here the so-called static part of memory is used to store the string. The content of the string cannot be changed.

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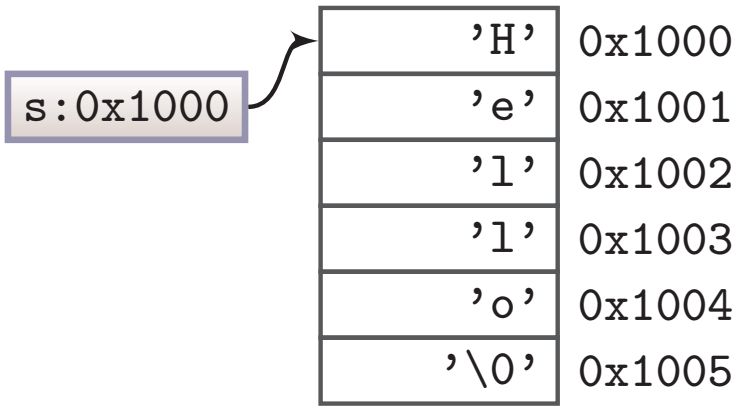


- Here the so-called static part of memory is used to store the string. The content of the string cannot be changed.
- We can modify value of s, however it is not recommended, because this stores the address of our string.

# Remarks

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- Character or text?

```
1 char s[] = "A"; /* two bytes: {'A', '\0'} */
2 char c = 'A';   /* one byte: 'A' */
```

# Remarks



- Character or text?

```c
char s[] = "A"; /* two bytes: {'A', '\0'} */
char c = 'A';   /* one byte: 'A' */
```

- A text can be empty, but there is no empty character

```c
char s[] = "";  /* one byte: {'\0'} */
char c = '';    /* ERROR, this is not possible */
```

# Reading and displaying strings

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- Strings are read and displayed with format code %s

```
1  char s[100] = "Hello";
2  printf("%s\n", s);
3  printf("Enter a word not longer than 99 characters: ");
4  scanf("%s", s);
5  printf("%s\n", s);
```

```
Hello
Enter a word not longer than 99 characters:  ghostbusters
ghostbusters
```

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```
Hello
Enter a word not longer than 99 characters:  ghostbusters
ghostbusters
```

- Why don't we have to pass the size for `printf`?
- Why don't we need the `&` in the `scanf` function?

# Reading and displaying strings



- `scanf` reads only until the first whitespace character. To read text consisting of several words, use the `gets` function:

```
1 char s[100];
2 printf("Enter a text - max. 99 characters long: ");
3 gets(s);
4 printf("%s\n", s);
```

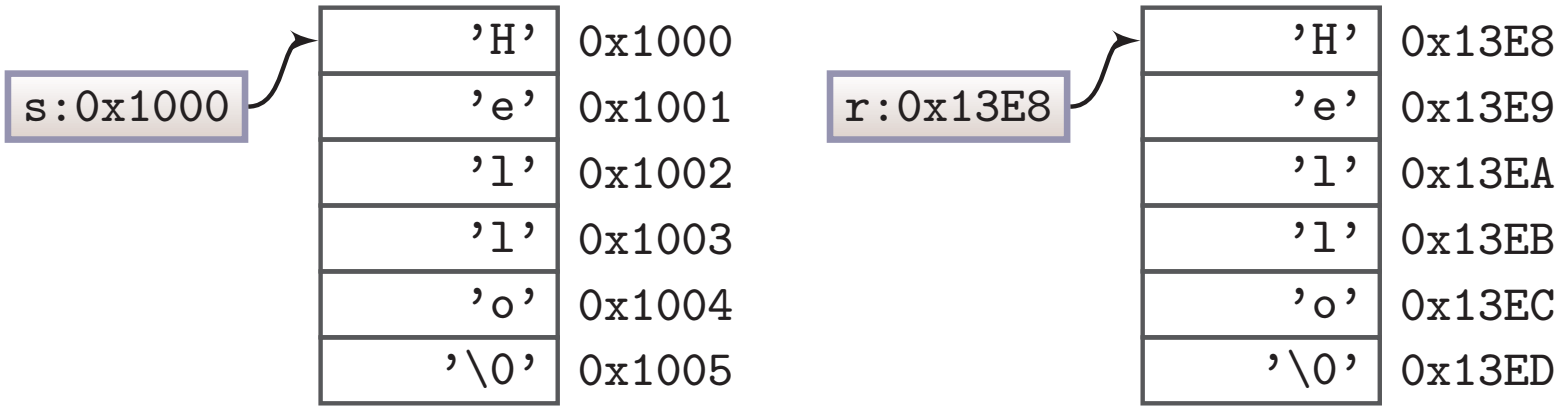
```
Enter a text - max.  99 characters long:  this is text
this is text
```

# Strings – typical mistakes



- Typical mistake: comparison of strings

```
1  char *s = "Hello";
2  char *r = "Hello";
3  if (s == r) /* what do we compare? */
4    ...
```



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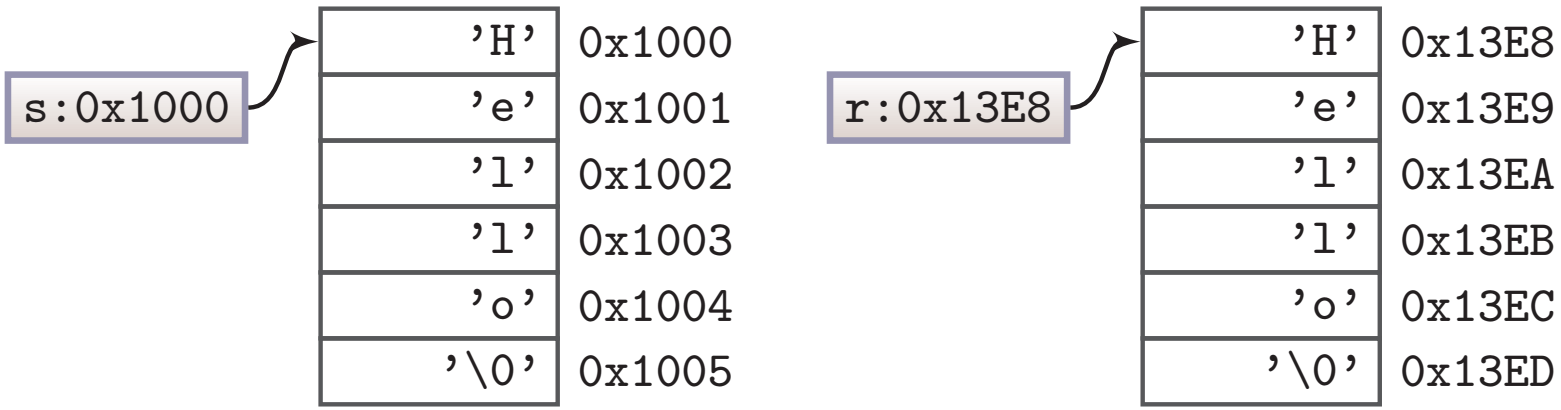


- The same mistake happens if defined as arrays

# String functions



- Comparing strings
- the result
  - positive, if s1 stands after s2 alphabetically
  - 0, if they are identical
  - negative, if s1 stands before s2 alphabetically

```
1  int strcmp(char *s1, char *s2) /* pointer-notation */
2  {
3    while (*s1 != '\0' && *s1 == *s2)
4    {
5      s1++;
6      s2++;
7    }
8    return *s1 - *s2;
9  }
```

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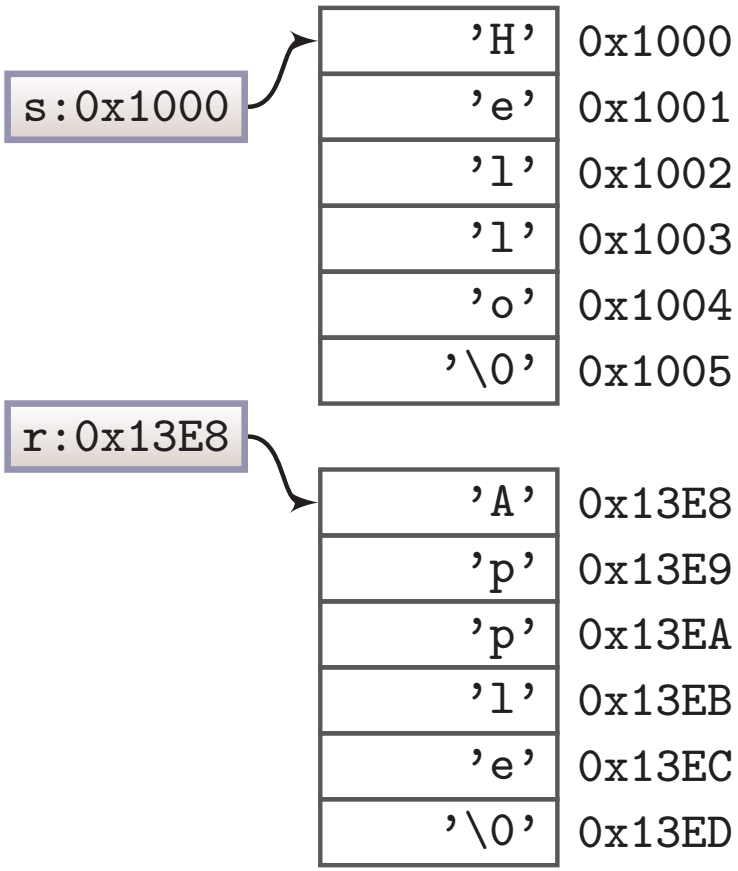
- Is it a problem, that s1 and s2 was changed during the check?
- Remark: In the solution we made use of the information that \0 is the 0 ASCII-code character!

# Strings – typical mistakes



- Typical mistake: string copy attempt

```
1 char *s = "Hello";
2 char *r = "Apple";
3 r = s; /* what do we copy */
```



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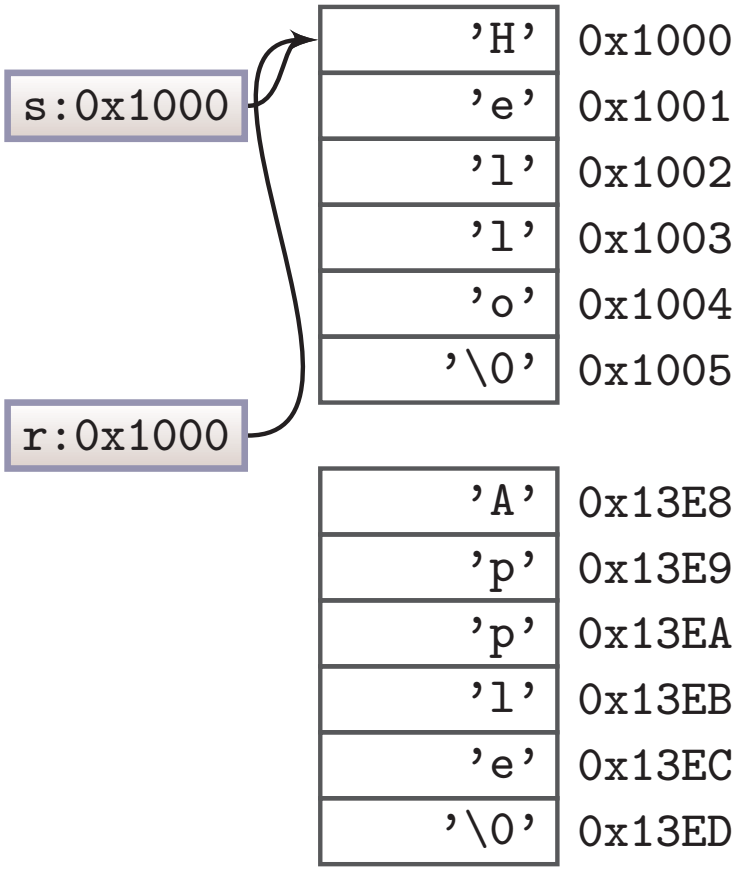

# Other string functions



- `#include <string.h>`
  - `strlen` length of string (without `\0`)
  - `strcmp` comparing strings
  - `strcpy` copying string
  - `strcat` concatenating strings
  - `strchr` search for character in string
  - `strstr` search for string in string
- `strcpy` and `strcat` functions copy 'without thinking', the user must provide the allocated memory for the resulting string!

Thank you for your attention.