# Strings – Dynamic memory management

## Basics of Programming 1


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# Content

Chapter 1

# Strings

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

# Strings

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- 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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- The same in a more simple way

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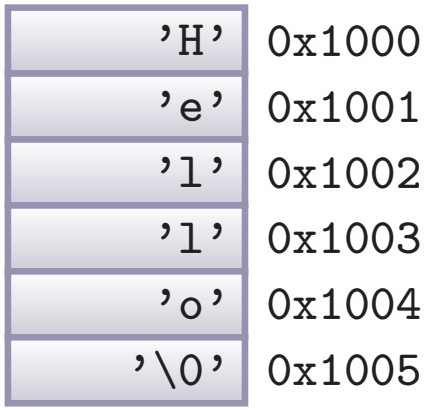

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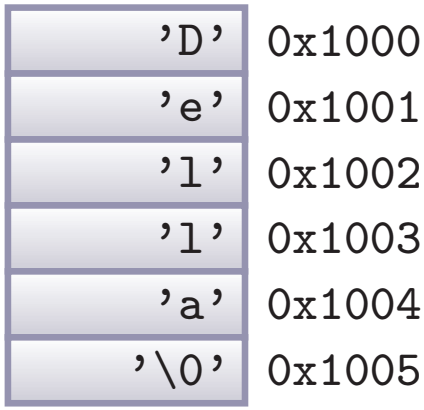


- Elements of s can be accessed with indexing or with pointer-arithmetics

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

# Defining strings as character arrays

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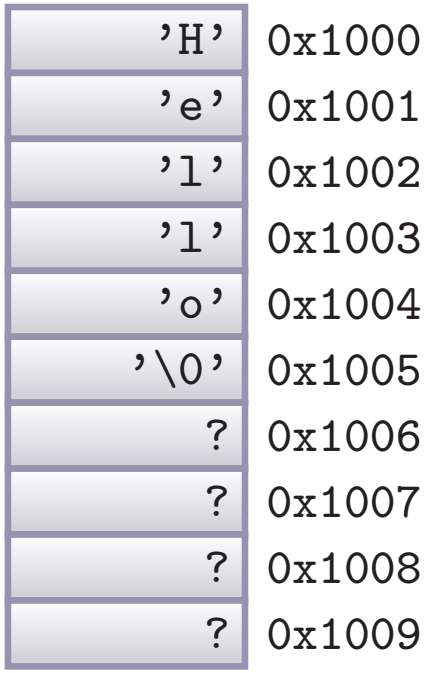
- We can allocate memory for a longer string than needed now, thus we have an overhead.

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



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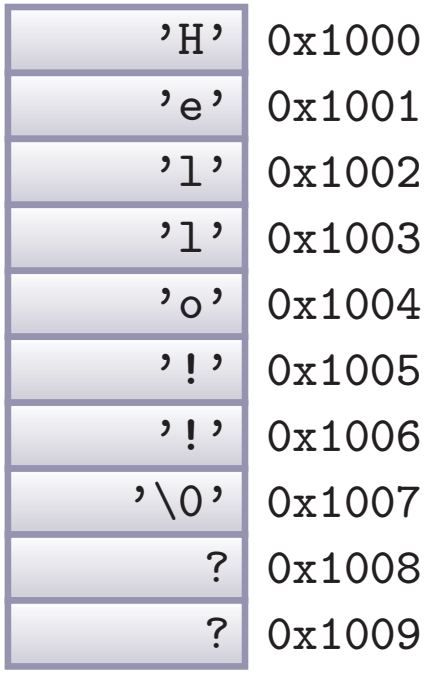


- Modification:

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

# Defining strings as character arrays

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

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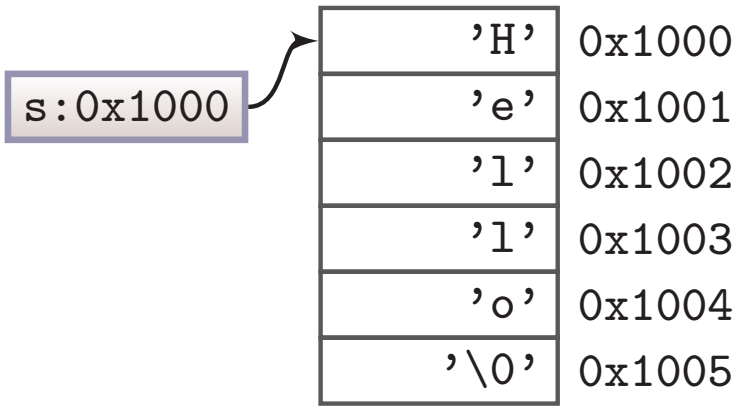

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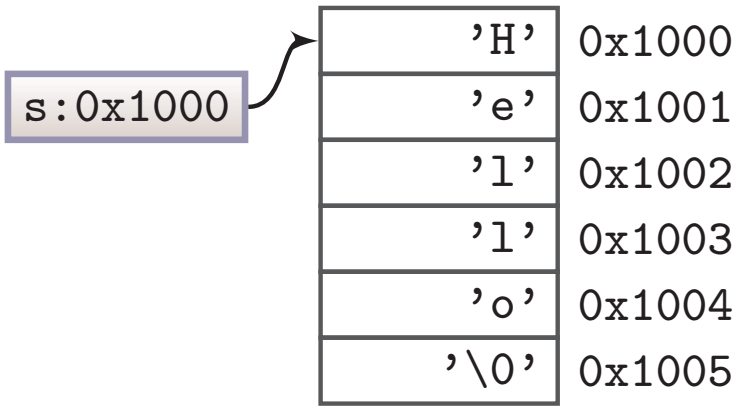


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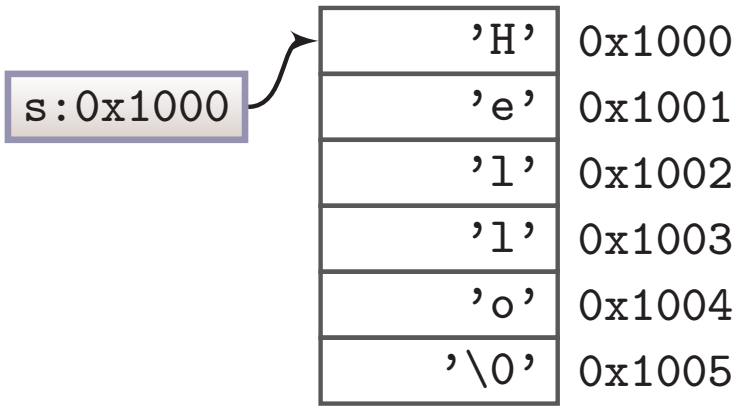


- Here the so-called static part of memory is used to store the string. The content of the string cannot be changed.
- We can modify value of s, however it is not recommended, because this stores the address of our string.

# 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



- Strings are read and displayed with format code %s

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

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

# Reading and displaying strings



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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
```

- 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

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- `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

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- 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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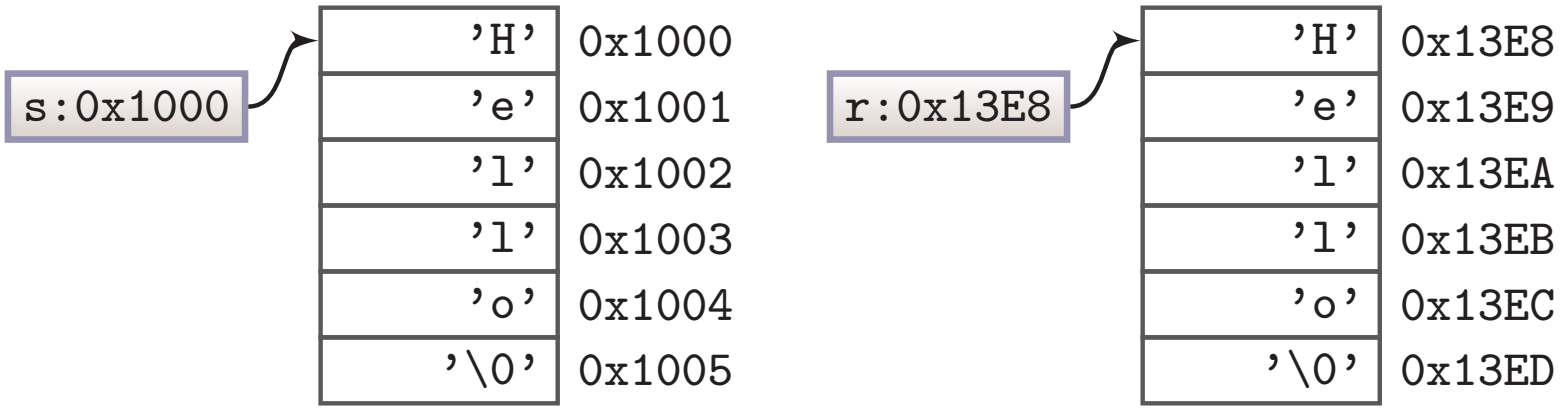

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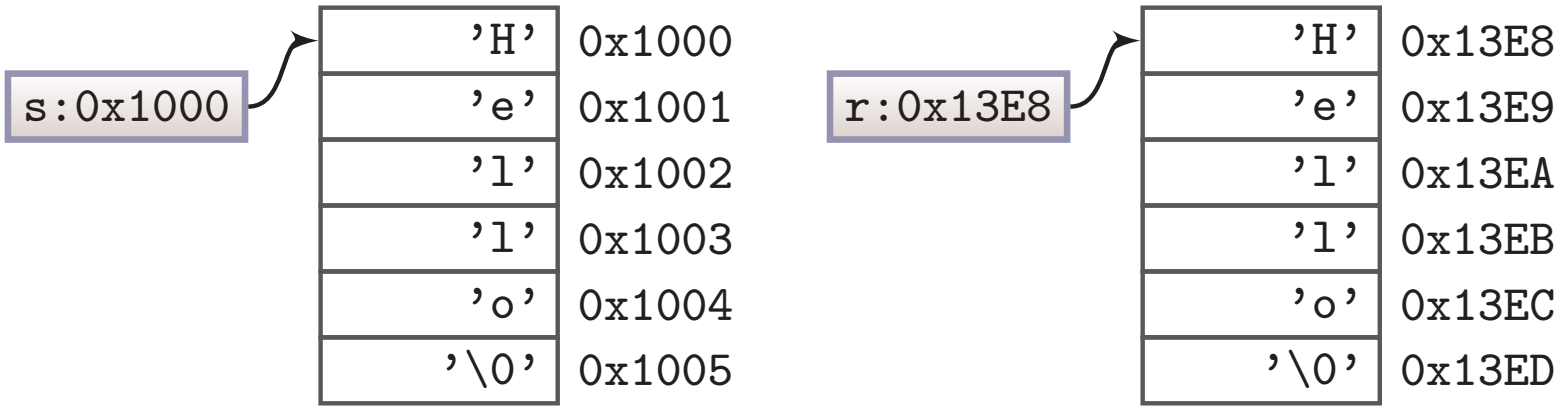


- The same mistake happens if defined as arrays

# 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

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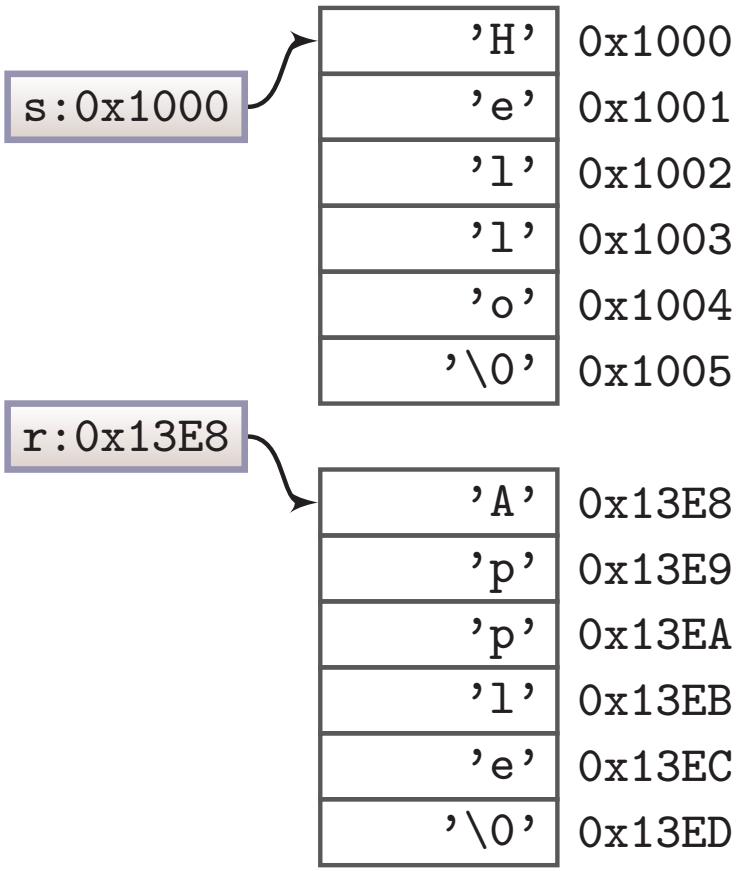
- Typical mistake: string copy attempt

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



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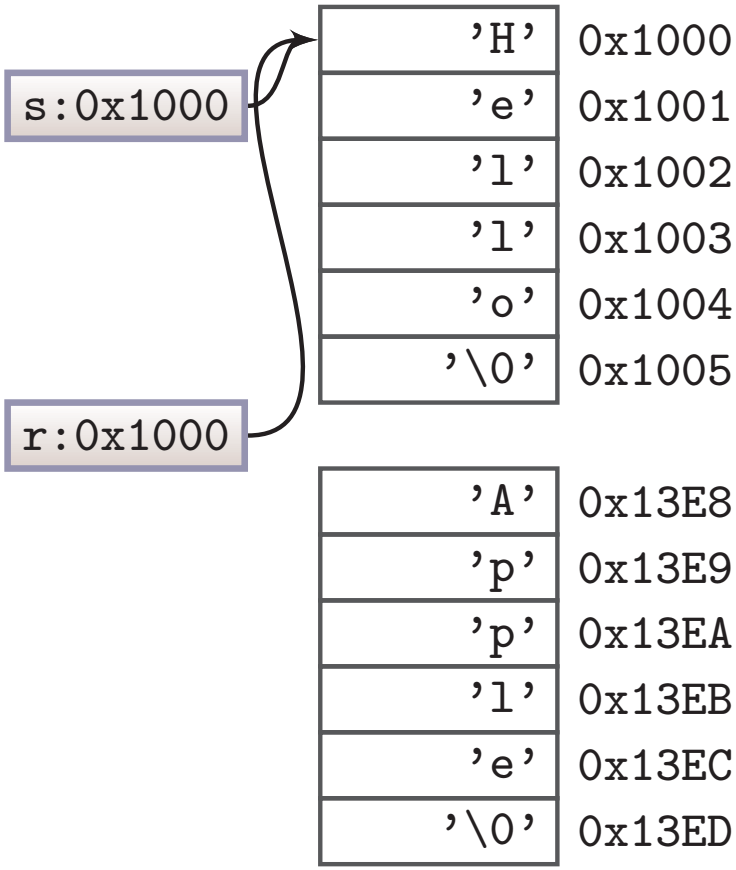

# Other string functions



- `#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!

Chapter 2

# Dynamic memory management

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DEPARTMENT OF NETWORKED SYSTEMS AND SERVICES

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- Let's not use more memory than needed!

1. We read the count (`n`)
2. We ask memory from the operating system for storing `n` integer numbers
3. We read and store the numbers, and print them in reversed order
4. We give back (hand over) the reserved memory place to the operating system

# Example

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```
1  int n, i;
2  int *p;
3
4  printf("How many numbers? ");
5  scanf("%d", &n);
6  p = (int*)malloc(n*sizeof(int));
7  if (p == NULL) return;
8
9  printf("Enter %d numbers:\n", n);
10 for (i = 0; i < n; ++i)
11   scanf("%d", &p[i]);
12
13 printf("Reversed:\n");
14 for (i = 0; i < n; ++i)
15   printf("%d ", p[n-i-1]);
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17 free(p);
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p:0x????

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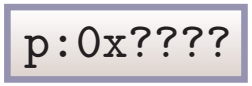


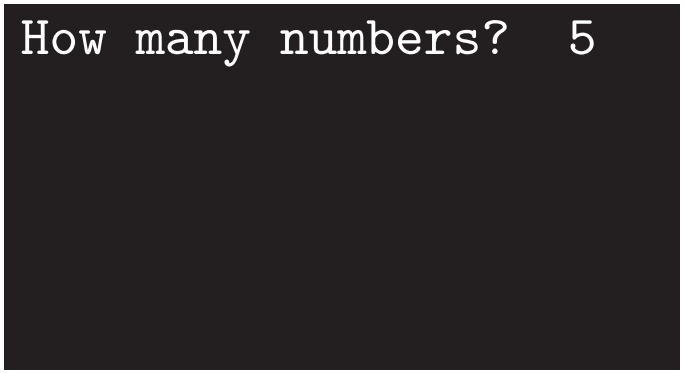

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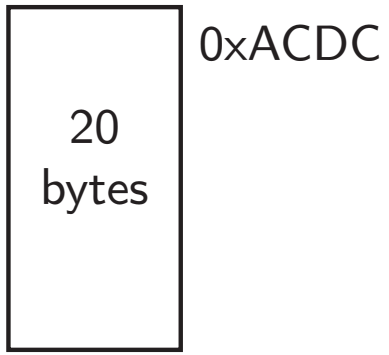


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```
How many numbers?  5
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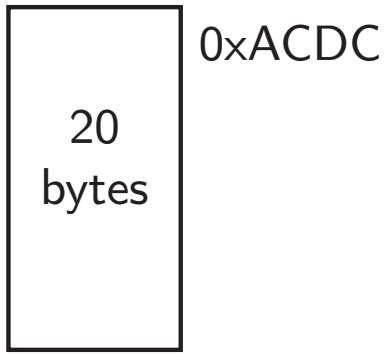


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DEPARTMENT OF NETWORKED SYSTEMS AND SERVICES

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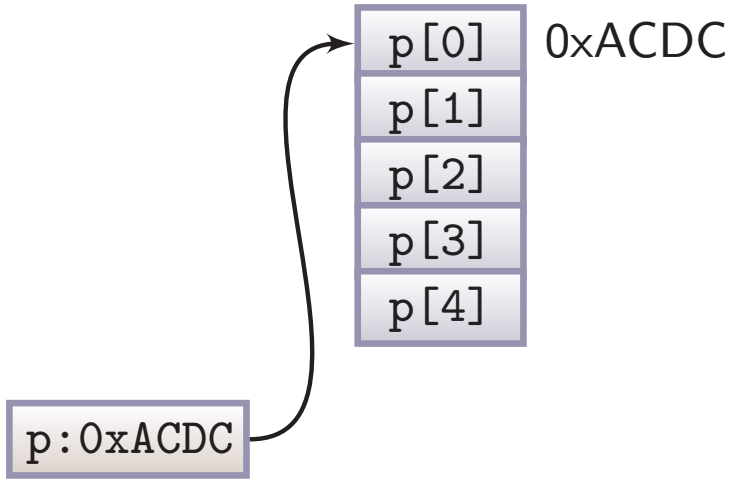


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DEPARTMENT OF NETWORKED SYSTEMS AND SERVICES

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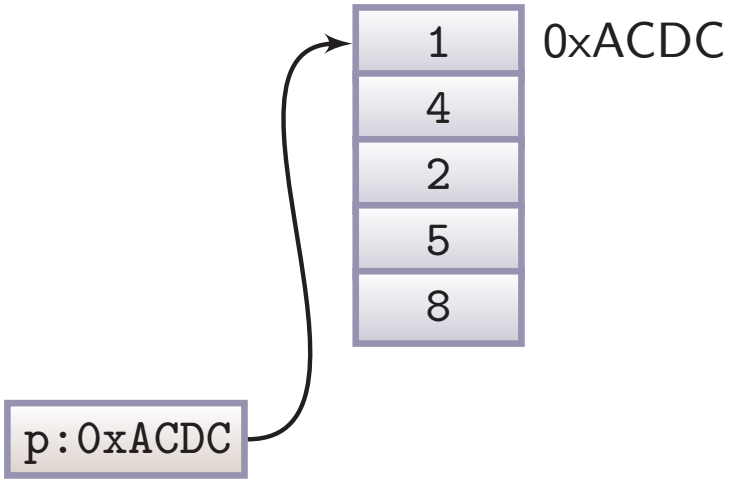


```
How many numbers?  5
Enter 5 numbers!
1 4 2 5 8
Reversed:
8 5 2 4 1
```

# Example

DEPARTMENT OF NETWORKED SYSTEMS AND SERVICES

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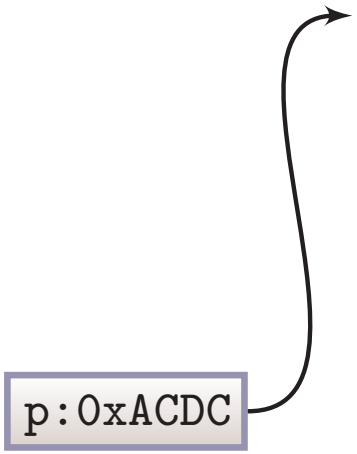


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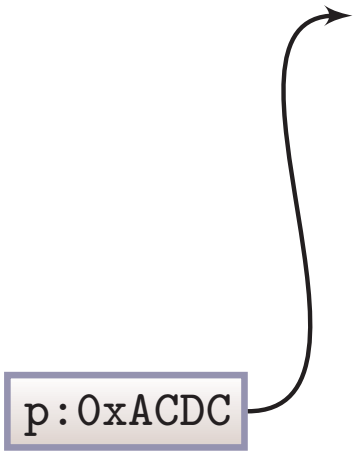


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DEPARTMENT OF NETWORKED SYSTEMS AND SERVICES

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link

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# The malloc and free functions – <stdlib.h>

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void *malloc(size_t size);
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- Allocates memory block of `size` bytes, and the address of the block is returned as `void*` type value

# The malloc and free functions – <stdlib.h>

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- Allocates memory block of `size` bytes, and the address of the block is returned as `void*` type value
- The returned `void*` "is only an address", we cannot de-refer it. We can use it only if converted (eg. to `int*`).

```
1 int *p; /* starting address of int array */
2 /* Memory allocation for 5 int */
3 p = (int *)malloc(5*sizeof(int));
```

# The malloc and free functions – <stdlib.h>

DEPARTMENT OF NETWORKED SYSTEMS AND SERVICES

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1 int *p; /* starting address of int array */
2 /* Memory allocation for 5 int */
3 p = (int *)malloc(5*sizeof(int));
```

- If there is not enough memory avaible, the return value is NULL. This must be checked always.

```
1 if (p != NULL)
2 {
3   /* using memory, and releasing it */
4 }
```

# The malloc and free functions – <stdlib.h>

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1 int *p = (int *)malloc(5*sizeof(int));
2 if (p != NULL)
3 {
4   /* using it */
5 }
6 free(p);  /* works even if NULL */
7 p = NULL; /* a useful step to remember */
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- As a nullpointer points to nowhere, a good practice is to set a pointer to NULL after usage, so we can see it is not in use.

# malloc – free

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- `malloc` and `free` go hand-in-hand,

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- for each malloc there is a free

```
1 char *WiFi = (char *)malloc(20*sizeof(char));
2 int *Tibet = (int *)malloc(23*sizeof(int));
3 ...
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- Good practice rules:
  - Release in the same function where allocated
  - Don't modify the pointer that was returned by malloc, if possible, use the same pointer for releasing
- If we cannot keep these rules, make a note in the code about this (comment)

# The calloc function – <stdlib.h>

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- Usage is almost the same as of `malloc`, except this performs the calculation `num*size`, and removes the garbage.
- The allocated block must be released in the same way: with `free`.

```
1 int *p = (int *)calloc(5, sizeof(int));
2 if (p != NULL)
3 {
4   /* using it */
5 }
6 free(p);
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- the new size can be smaller r larger than the earlier size
- if needed, the earlier content is copied to the new place, the elements are not initialized
- its return value is the starting address of the new place

```
1 int *p = (int *)malloc(3*sizeof(int));
2 p[0] = p[1] = p[2] = 8;
3 p = realloc(p, 5*sizeof(int));
4 p[3] = p[4] = 8;
5 ...
6 free(p);
```

# Example

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1. The function determines the length of the two strings,
2. allocates memory for the result,
3. copies the first string into the result string,
4. copies the second string after it.

- Of course, this function cannot release the allocated memory, this must be done in the calling program segment

# Example

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```c
/* concatenate -- concatenating two strings
  Dynamic allocation, returning with address.
*/
char *concatenate(char *s1, char *s2){
    size_t l1 = strlen(s1);
    size_t l2 = strlen(s2);
    char *s = (char *)malloc((l1+l2+1)*sizeof(char));
    if (s != NULL)    {
        strcpy(s, s1);
        strcpy(s+l1, s2); /* or strcat(s, s2) */
    }
    return s;
}
```

link

# Example

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## Usage of the function

```c
char word1[] = "partner", word2[] = "ship";

char *res1 = concatenate(word1, word2);
char *res2 = concatenate(word2, word1);
res2[0] = 'w';

printf("%s\n%s", res1, res2);

/* The function did allocate memory, release it! */
free(res1);
free(res2);
```

link

```
partnership
whippartner
```

Thank you for your attention.