

Lecture 13 - Strings

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```
char s1[6] = {'H', 'e', 'l', 'l', 'o', '\0'};
```

```
char s2[6] = "Hello";
```

```
char s3[6] = "He" "llo";
```

H	e	l	l	o	\0
---	---	---	---	---	----

Introduction

- This lecture covers both *string constants* (or *literals*, as they're called *in the C standard*) and *string variables*.
- Strings are *arrays of characters* in which a *special character*—the *null character*—marks the end.
- The C library provides *a collection of functions* for *working with strings*.

String Literals

- A ***string literal*** is a sequence of characters enclosed within double quotes:
`"When you come to a fork in the road, take it."`
- String literals may contain escape sequences.
- Character escapes often appear in `printf` and `scanf` format strings.
- For example, each `\n` character in the string
`"Candy\nIs dandy\nBut liquor\nIs quicker.\n --Ogden Nash\n"`

causes the cursor to advance to the next line:

```
Candy
Is dandy
But liquor
Is quicker.
  --Ogden Nash
```

Continuing a String Literal

- There are **two ways** to continue a string literal.
- The **backslash character** (`\`) can be **used to continue a string literal** from one line to the next:

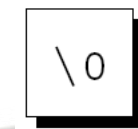
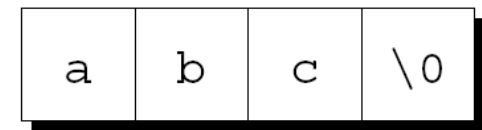
```
printf("When you come to a fork in the road, take it. \n--Yogi Berra");
```

- When **two or more string literals are adjacent**, the **compiler will join them into a single string**. This rule **allows us to split a string literal over two or more lines**:

```
printf("When you come to a fork in the road, take it. \n--Yogi Berra");
```

How String Literals Are Stored

- When a C compiler encounters a string literal of length n , it sets aside $n + 1$ bytes of memory for the string.
- This memory will contain the characters in the string, plus one extra character—the **null character**—to mark the end of the string.
- The null character is a byte escape sequence whose bits are all zero, so it's represented by the `\0`.
- The string literal `"abc"` is stored as an array of four characters:
- Similarly, the string `" "` is stored as a single null character:



How String Literals Are Stored (cont.)

- Since a **string literal** is stored as an array, the **compiler treats it as a pointer of type `char *`**.
- Both `printf` and `scanf` **expect a value of type `char *` as their first argument**.
- The following call of `printf` passes the **address of `"abc"` (a pointer to where the letter `a` is stored in memory)**:

```
printf("abc");
```

Operations on String Literals

- We can use a string literal **wherever C allows a `char *` pointer**:

```
char *p;  
  
p = "abc";
```
- This assignment makes **p point to the first character of the string**.

Operations on String Literals (cont.)

- String literals **can be subscripted**:

```
char ch;
```

```
ch = "abc"[1];
```

The new value of **ch** will be the letter **b**.

- A function that **converts a number between 0 and 15 into the equivalent hex digit**:

```
char digit_to_hex_char(int digit)
{
    return "0123456789ABCDEF"[digit];
}
```


Operations on String Literals (cont.)

- Attempting to modify a string literal causes undefined behavior:

```
char *p = "abc";
```

```
*p = 'd';    /*** WRONG ***/
```

- A program that tries to change a string literal **may crash** or **behave erratically**.

String Literals versus Character Constants

- A string literal containing a single character isn't the same as a character constant.

- `"a"` is represented by *a pointer (`char *`)*.

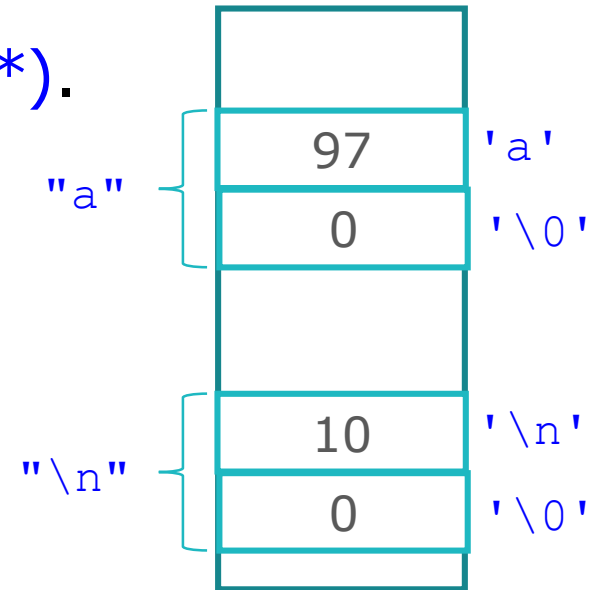
- `'a'` is represented by *an integer*.

- A **legal call** of `printf`:

```
printf("\n");
```

- An **illegal call**:

```
printf('\n');    /* ** WRONG ** */
```



String Variables

- Any one-dimensional array of characters can be used to store a string.
- A string must be terminated by a null character.
- Difficulties with this approach:
 - It can be hard to tell whether an array of characters is being used as a string.
 - String-handling functions must be careful to deal properly with the null character.
 - Finding the length of a string requires searching for the null character.

String Variables (cont.)

- If a string variable needs to hold **80 characters**, it **must** be declared to **have length 81**:

```
#define STR_LEN 80
```

```
...
```

```
char str[STR_LEN+1];
```

- **Adding 1** to the desired length **allows room for the null character** at the end of the string.
- **Defining a macro** that represents 80 and **then adding 1** separately **is a common practice**.

String Variables (cont.)

- Be sure to leave room for the null character when declaring a string variable.
- Failing to do so may cause unpredictable results when the program is executed.
- The actual length of a string depends on the position of the terminating null character.
- An array of `STR_LEN + 1` characters can hold strings with lengths between 0 and `STR_LEN`.

Initializing a String Variable

- A string variable **can be initialized** at the same time it's **declared**:

```
char date1[8] = "June 14";
```

- The **compiler will automatically add a null character** so that `date1` can be used as a string:

date1	J	u	n	e		1	4	\0
-------	---	---	---	---	--	---	---	----

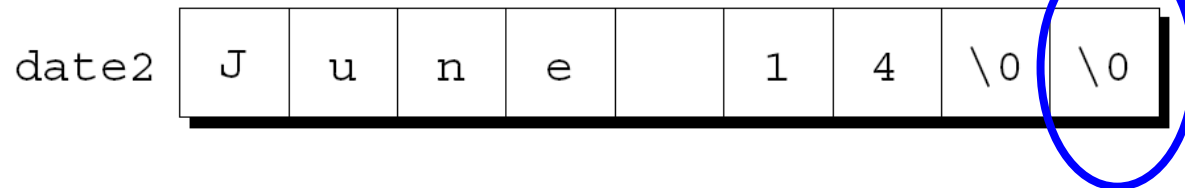
- `"June 14"` **is not a string literal** in this context.
- Instead, **C views it as** an abbreviation for an **array initializer**.

Initializing a String Variable (cont.)

- If the initializer is too short to fill the string variable, the compiler adds extra null characters:

```
char date2[9] = "June 14";
```

Appearance of date2:

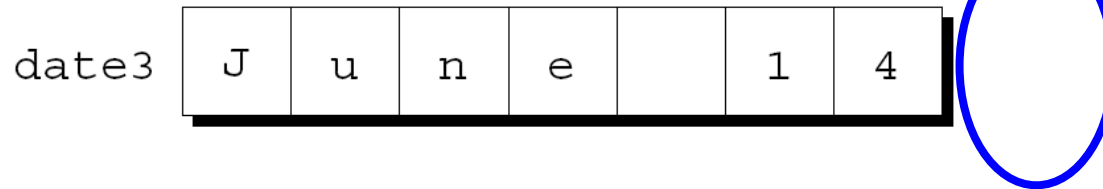


Initializing a String Variable (cont.)

- An **initializer** for a string variable **can't be longer than the variable**, but it **can be the same length**:

```
char date3[7] = "June 14";
```

- There's **no room for the null character**, so the **compiler makes no attempt to store one**:



Initializing a String Variable (cont.)

- The **declaration** of a string variable **may omit its length**, in which case the **compiler computes it**:

```
char date4[] = "June 14";
```
- The **compiler sets aside eight characters** for `date4`, **enough to store the characters** in `"June 14"` **plus a null character**.
- **Omitting the length** of a string variable **is especially useful if the initializer is long**, since computing the length by hand is error-prone.

Character Arrays versus Character Pointers

- The declaration

```
char date[] = "June 14";
```

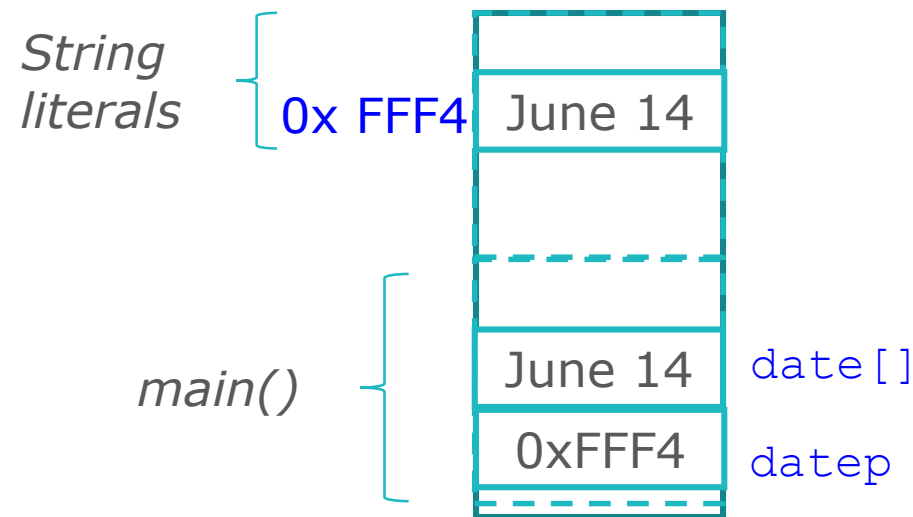
declares `date` to be **an array**,

- The similar-looking

```
char *datep = "June 14";
```

declares `datep` to be **a pointer**.

- Thanks to the close relationship between arrays and pointers, **either version can be used as a string**.



Character Arrays versus Character Pointers (cont.)

- However, there are **significant differences** between the two versions of `date`.
- In the **array version**, the **characters stored in `date` can be modified**.
In the **pointer version**, `datep` points to a string literal that **shouldn't be modified**.
- In the **array version**, `date` **is an array name**.
In the **pointer version**, `datep` **is a variable that can point to other strings**.

Character Arrays versus Character Pointers (cont.)

- The declaration

```
char *p;
```

does not allocate space for a string.

- Before we can use `p` as a string, it must point to an array of characters.
- One possibility is to make `p` point to a string variable:

```
char str[STR_LEN+1], *p;  
p = str;
```
- Another possibility is to make `p` point to a dynamically allocated string.

Character Arrays versus Character Pointers (cont.)

- Using an uninitialized pointer variable as a string is a serious error.
- An attempt at building the string "abc":

```
char *p;
```

```
p[0] = 'a';      /* ** WRONG ** */  
p[1] = 'b';      /* ** WRONG ** */  
p[2] = 'c';      /* ** WRONG ** */  
p[3] = '\\0';    /* ** WRONG ** */
```

- Since `p` hasn't been initialized, this causes undefined behavior.

Reading and Writing Strings

- Writing a string is easy using either `printf` or `puts`.
- Reading a string is a bit harder, because the input may be longer than the string variable into which it's being stored.
- To read a string in a single step, we can use either `scanf` or `gets`.
- As an alternative, we can read strings one character at a time.

Writing Strings Using `printf` and `puts`

- The `%s` conversion specification allows `printf` to write a string:

```
char str[] = "Are we having fun yet?";
```

```
printf("%s\n", str);
```

The output will be

Are we having fun yet?

- `printf` writes the characters in a string one by one until it encounters a null character.

Writing Strings Using `printf` and `puts` (cont.)

- To **print part of a string**, use the conversion specification `%.ps`.
- ***p*** is the **number of characters** to be displayed.
- The statement

```
printf("%.6s\n", str);
```

will print

Are we

Writing Strings Using `printf` and `puts` (cont.)

- The `%ms` conversion will display a string in a field of size `m`.
- If the string has fewer than `m` characters, it will be right-justified within the field.
- To force left justification instead, we can put a minus sign in front of `m`.
- The `m` and `p` values can be used in combination.
- A conversion specification of the form `%m.ps` causes the first `p` characters of a string to be displayed in a field of size `m`.

Writing Strings Using `printf` and `puts` (cont.)

- `printf` isn't the only function that can write strings.
- The C library also provides `puts`:
`puts(str);`
- After writing a string, `puts` always writes an additional new-line character.

Reading Strings Using `scanf` and `gets`

- The `%s` conversion specification allows `scanf` to read a string into a character array:

```
scanf("%s", str);
```
- `str` is treated as a pointer, so there's no need to put the `&` operator in front of `str`.
- When `scanf` is called, it skips white space, then reads characters and stores them in `str` until it encounters a white-space character.
- `scanf` always stores a null character at the end of the string.

Reading Strings Using `scanf` and `gets` (cont.)

- `scanf` won't usually read a full line of input.
- A new-line character will cause `scanf` to stop reading, but so will a space or tab character.
- To read an entire line of input, we can use `gets`.
- Properties of `gets`:
 - Doesn't skip white space before starting to read input.
 - Reads until it finds a new-line character.
 - Discards the new-line character instead of storing it; the null character takes its place.

Reading Strings Using `scanf` and `gets` (cont.)

- Consider the following program fragment:

```
char sentence[SENT_LEN+1];  
  
printf("Enter a sentence:\n");  
scanf("%s", sentence);
```

- Suppose that after the prompt

Enter a sentence:

the user enters the line

To C, or not to C: that is the question.

- `scanf` will store the string "To" in sentence.

Reading Strings Using `scanf` and `gets` (cont.)

- Suppose that we **replace** `scanf` **by** `gets`:
`gets(sentence);`
- When the user enters the same input as before, `gets` **will store the string**
`" To C, or not to C: that is the question."`
in `sentence`.

Reading Strings Using `scanf` and `gets` (cont.)

- As they read characters into an array, `scanf` and `gets` have no way to detect when it's full.
- Consequently, they may store characters past the end of the array, causing undefined behavior.
- `scanf` can be made safer by using the conversion specification `%ns` instead of `%s`.
- `n` is an integer indicating the maximum number of characters to be stored.
- `gets` is inherently unsafe; `fgets` is a much better alternative.

Reading Strings Character by Character (cont.)

- Programmers often write their own input functions.
- Issues to consider:
 - Should the function skip white space before beginning to store the string?
 - What character causes the function to stop reading: a new-line character, any white-space character, or some other character? Is this character stored in the string or discarded?
 - What should the function do if the input string is too long to store: discard the extra characters or leave them for the next input operation?

Reading Strings Character by Character (cont.)

- Suppose we need a function that (1) doesn't skip white-space characters, (2) stops reading at the first new-line character (which isn't stored in the string), and (3) discards extra characters.
- A prototype for the function:

```
int read_line(char str[], int n);
```
- If the input line contains more than `n` characters, `read_line` will discard the additional characters.
- `read_line` will return the number of characters it stores in `str`.

Reading Strings Character by Character (cont.)

- `read_line` consists primarily of a loop that calls `getchar` to read a character and then stores the character in `str`, provided that there's room left:

```
int read_line(char str[], int n)
{
    int ch, i = 0;

    while ((ch = getchar()) != '\n')
        if (i < n)
            str[i++] = ch;
    str[i] = '\0';    /* terminates string */
    return i;         /* number of characters stored */
}
```

- `ch` has `int` type rather than `char` type because `getchar` returns an `int` value.

Reading Strings Character by Character (cont.)

- Before returning, `read_line` puts a null character at the end of the string.
- Standard functions such as `scanf` and `gets` automatically put a null character at the end of an input string.
- If we're writing our own input function, we must take on that responsibility.

Accessing the Characters in a String

- Since strings are stored as arrays, **we can use subscripting to access the characters** in a string.
- **To process every character** in a string `s`, **we can set up a loop** that increments a counter `i` and selects characters via the expression `s[i]`.
- A function that **counts the number of spaces** in a string:

```
int count_spaces(const char s[])
{
    int count = 0, i;
    for (i = 0; s[i] != '\0'; i++)
        if (s[i] == ' ')
            count++;
    return count;
}
```

Accessing the Characters in a String (cont.)

- A version that **uses pointer arithmetic instead of array subscripting** :

```
int count_spaces(const char *s)
{
    int count = 0;

    for (; *s != '\0'; s++)
        if (*s == ' ')
            count++;
    return count;
}
```

```
int count_spaces(const char s[])
{
    int count = 0, i;
    for (i = 0; s[i] != '\0'; i++)
        if (s[i] == ' ')
            count++;
    return count;
}
```

Accessing the Characters in a String (cont.)

- Questions raised by the `count_spaces` example:
 - *Is it better to use array operations or pointer operations to access the characters in a string?*
 - > We can use either or both. Traditionally, C programmers lean toward using pointer operations.
 - *Should a string parameter be declared as an array or as a pointer?*
 - > There's no difference between the two.
 - *Does the form of the parameter (`s[]` or `*s`) affect what can be supplied as an argument?*
 - > No.

Using the C String Library

- Some programming languages provide operators that can copy strings, compare strings, concatenate strings, select substrings, and the like.
- C's operators, in contrast, are essentially useless for working with strings.
- Strings are treated as arrays in C, so they're restricted in the same ways as arrays.
- In particular, they can't be copied or compared using operators.

Using the C String Library (cont.)

- Copying a string into a character array using the = operator is not possible:

```
char str1[10], str2[10];
```

```
...
```

```
str1 = "abc";    /*** WRONG ***/
```

```
str2 = str1;    /*** WRONG ***/
```

Using an array name as the left operand of = is illegal.

- *Initializing* a character array using = is legal, though:

```
char str1[10] = "abc";
```

In this context, = is not the assignment operator.

Using the C String Library (cont.)

- Attempting to **compare strings** using a **relational** or **equality** operator is legal but won't produce the desired result:

```
if (str1 == str2) ...    /*** WRONG ***/
```

- This statement **compares** `str1` and `str2` as *pointers*.
- Since `str1` and `str2` have different addresses, the expression `str1 == str2` must have the value 0.

Using the C String Library (cont.)

- The **C library** provides a rich set of functions for performing operations on **strings**.
- Programs that need string operations should contain the following line:

```
#include <string.h>
```
- In subsequent examples, assume that `str1` and `str2` are character arrays used as strings.

The `strcpy` (String Copy) Function

- **Prototype** for the `strcpy` function:
`char *strcpy(char *s1, const char *s2);`
- `strcpy` **copies** the **string** `s2` **into** the **string** `s1`.
 - To be precise, we should say “`strcpy` copies the string pointed to by `s2` into the array pointed to by `s1`.”
- `strcpy` **returns** `s1` (a pointer to the destination string).

The strcpy (String Copy) Function (cont.)

- A call of `strcpy` that stores the string "abcd" in `str2`:

```
strcpy(str2, "abcd");
```

```
/* str2 now contains "abcd" */
```
- A call that copies the contents of `str2` into `str1`:

```
strcpy(str1, str2);
```

```
/* str1 now contains "abcd" */
```
- In the call `strcpy(str1, str2)`, **strcpy has no way to check** that the **str2 string will fit** in the array pointed to by `str1`.
- **If it doesn't, undefined behavior occurs.**

The `strncpy` (String Copy) Function

- Calling the `strncpy` function is a safer, albeit slower, way to copy a string.
- `strncpy` has a third argument that limits the number of characters that will be copied.
- `strncpy` will leave `str1` without a terminating null character if the length of `str2` is greater than or equal to the size of the `str1` array.
- A safer way to use `strncpy`:

```
strncpy(str1, str2, sizeof(str1) - 1);  
str1[sizeof(str1)-1] = '\0';
```
- The second statement guarantees that `str1` is always null-terminated.

The `strlen` (String Length) Function

- Prototype for the `strlen` function:

```
size_t strlen(const char *s);
```

- `size_t` is a typedef name that represents one of C's unsigned integer types.
- `strlen` returns the length of a string `s`, not including the null character.
- Examples:

```
int len;
```

```
len = strlen("abc"); /* len is now 3 */
```

```
len = strlen(""); /* len is now 0 */
```

```
strcpy(str1, "abc");
```

```
len = strlen(str1); /* len is now 3 */
```

The `strcat` (String Concatenation) Function

- Prototype for the `strcat` function:

```
char *strcat(char *s1, const char *s2);
```

- `strcat` **appends** the contents of the **string** `s2` **to** the **end of** the **string** `s1`.
- It **returns** `s1` (a pointer to the **resulting string**).
- `strcat` **examples**:

```
strcpy(str1, "abc");  
strcat(str1, "def");  
/* str1 now contains "abcdef" */  
strcpy(str1, "abc");  
strcpy(str2, "def");  
strcat(str1, str2);  
/* str1 now contains "abcdef" */
```

The `strcat` (String Concatenation) Function (cont.)

- As with `strcpy`, the value returned by `strcat` is normally discarded.
- The following example shows how the return value might be used:

```
strcpy(str1, "abc");  
strcpy(str2, "def");  
strcat(str1, strcat(str2, "ghi"));  
/* str1 now contains "abcdefghi";  
   str2 contains "defghi" */
```


The `strcat` (String Concatenation) Function (cont.)

- `strcat(str1, str2)` causes **undefined behavior** if the **`str1` array isn't long enough** to accommodate the characters from `str2`.
- Example:

```
char str1[6] = "abc";  
  
strcat(str1, "def");    /*** WRONG ***/
```
- `str1` is limited to six characters, causing `strcat` to write past the end of the array.

The `strncat` (String Concatenation) Function

- The `strncat` function is a **safer but slower** version of `strcat`.
- **Like `strncpy`**, it has **a third argument that limits the number of characters** it will copy.
- A call of `strncat`:

```
strncat(str1, str2, sizeof(str1) - strlen(str1) - 1);
```
- `strncat` **will terminate** `str1` **with a null character**, which **isn't included in the third argument**.

The strcmp (String Comparison) Function

- Prototype for the strcmp function:

```
int strcmp(const char *s1, const char *s2);
```

- strcmp **compares** the strings **s1** and **s2**, **returning a value less than, equal to, or greater than 0**, depending on whether **s1** is less than, equal to, or greater than **s2**.

- **Testing** whether **str1** is less than **str2**:

```
if (strcmp(str1, str2) < 0)    /* is str1 < str2? */
```

- **Testing** whether **str1** is less than or equal to **str2**:

```
if (strcmp(str1, str2) <= 0) /* is str1 <= str2? */
```

- By choosing the proper operator (**<**, **<=**, **>**, **>=**, **==**, **!=**), **we can test any possible relationship** between **str1** and **str2**.

The strcmp (String Comparison) Function (cont.)

- As it compares two strings, **strcmp** looks at the numerical codes for the characters in the strings.
- Important properties of ASCII:
 - A–Z, a–z, and 0–9 have consecutive codes.
 - All upper-case letters are less than all lower-case letters.
 - Digits are less than letters.
 - Spaces are less than all printing characters.

ASCII value	Character	ASCII value	Character	ASCII value	Character
000	^@	043	+	086	V
001	^A	044	,	087	W
002	^B	045	-	088	X
003	^C	046	.	089	Y
004	^D	047	/	090	Z
005	^E	048	0	091	[
006	^F	049	1	092	\
007	^G	050	2	093]
008	^H	051	3	094	^
009	^I	052	4	095	_
010	^J	053	5	096	`
011	^K	054	6	097	a
012	^L	055	7	098	b
013	^M	056	8	099	c
014	^N	057	9	100	d
015	^O	158	:	101	e
016	^P	059	;	102	f
017	^Q	060	<	103	g
018	^R	061	=	104	h
019	^S	062	>	105	i
020	^T	063	?	106	j
021	^U	064	@	107	k
022	^V	065	A	108	l
023	^W	066	B	109	m
024	^X	067	C	110	n
025	^Y	068	D	111	o
026	^Z	069	E	112	p
027	^[	070	F	113	q
028	^\ [space]	071	G	114	r
029	^]	072	H	115	s
030	^^	073	I	116	t
031	^-	074	J	117	u
032		075	K	118	v
033	!	076	L	119	w
034	"	077	M	120	x
035	#	078	N	121	y
036	\$	079	O	122	z
037	%	080	P	123	{
038	&	081	Q	124	|
039	'	082	R	125	}
040	(	083	S	126	~
041	)	084	T	127	DEL
042	*	085	U		

The strcmp (String Comparison) Function (cont.)

- strcmp considers **s1 to be less than s2** if either one of the following conditions is satisfied:
 - The **first i characters of s1 and s2 match**, but the **$(i+1)$ st character of s1 is less** than the $(i+1)$ st character of s2.
 - **All characters of s1 match s2**, but **s1 is shorter** than s2.

"abc" < "abd"

"abc" < "abcd"

Program: Printing a One-Month Reminder List

- The `remind.c` program prints a **one-month list of daily reminders**.
- The **user will enter a series of reminders**, with each **prefixed by a day** of the month.
- When the **user enters 0** instead of a valid day, the program will **print a list of all reminders** entered, **sorted by day**.
- The next slide shows a session with the program.

Program: Printing a One-Month Reminder List (cont.)

```
Enter day and reminder: 24 Susan's birthday
Enter day and reminder: 5 6:00 - Dinner with Marge and Russ
Enter day and reminder: 26 Movie - "Chinatown"
Enter day and reminder: 7 10:30 - Dental appointment
Enter day and reminder: 12 Movie - "Dazed and Confused"
Enter day and reminder: 5 Saturday class
Enter day and reminder: 12 Saturday class
Enter day and reminder: 0
```

Day Reminder

```
5 Saturday class
5 6:00 - Dinner with Marge and Russ
7 10:30 - Dental appointment
12 Saturday class
12 Movie - "Dazed and Confused"
24 Susan's birthday
26 Movie - "Chinatown"
```

Program: Printing a One-Month Reminder List (cont.)

- Overall strategy:
 - **Read** a series of day-and-reminder combinations.
 - **Store them in order** (sorted by day).
 - **Display** them.
- `scanf` will be used to **read the days**.
- `read_line` will be used to **read the reminders**.

Program: Printing a One-Month Reminder List (cont.)

- The **strings** will be **stored in a two-dimensional array** of characters.
- **Each row** of the array **contains one string**.
- Actions taken after the program reads a day and its associated reminder:
 - **Search the array** to determine where the day belongs, **using `strcmp` to do comparisons**.
 - **Use `strcpy` to move all strings below that point** down one position.
 - **Copy the day into the array and call `strcat` to append the reminder to the day**.

Program: Printing a One-Month Reminder List (cont.)

- One complication: **how to right-justify the days** in a two-character field.
- A solution: **use `scanf` to read the day into an integer variable**, then **call `sprintf` to convert** the day back into string form.
- `sprintf` is **similar to `printf`**, except that it writes **output into a string**.
- The following call **writes the value of `day` into `day_str`**.

```
sprintf(day_str, "%2d", day);
```
- The following call of `scanf` **ensures that the user doesn't enter more than two digits**:

```
scanf("%2d", &day);
```

Program: Printing a One-Month Reminder List (cont.)

```
#include <stdio.h>                                remind.c
#include <string.h>
#define MAX_REMIND 50    /* maximum number of reminders */
#define MSG_LEN 60      /* max length of reminder message */
int read_line(char str[], int n);
int main(void)
{
    char reminders[MAX_REMIND][MSG_LEN+3];
    char day_str[3], msg_str[MSG_LEN+1];
    int day, i, j, num_remind = 0;

    for (;;) {
        if (num_remind == MAX_REMIND) {
            printf("-- No space left --\n");
            break;
        }
        printf("Enter day and reminder: ");
        scanf("%2d", &day);
        if (day == 0)
            break;
        sprintf(day_str, "%2d", day);
        read_line(msg_str, MSG_LEN);
    }
}
```

Program: Printing a One-Month Reminder List (cont.)

```
for (i = 0; i < num_remind; i++)
    if (strcmp(day_str, reminders[i]) < 0)
        break;
for (j = num_remind; j > i; j--)
    strcpy(reminders[j], reminders[j-1]);

strcpy(reminders[i], day_str);
strcat(reminders[i], msg_str);
num_remind++;
}

printf("\nDay Reminder\n");
for (i = 0; i < num_remind; i++)
    printf(" %s\n", reminders[i]);

return 0;
}
```

```
int read_line(char str[], int n)
{
    int ch, i = 0;

    while ((ch = getchar()) != '\n')
        if (i < n)
            str[i++] = ch;
    str[i] = '\0';
    return i;
}
```

String Idioms

- Functions that manipulate strings are a rich source of idioms.
- We'll explore **some of the most famous idioms** by using them **to write the `strlen` and `strcat` functions.**

Searching for the End of a String

- A version of `strlen` that searches for the end of a string, using a variable to keep track of the string's length:

```
size_t strlen(const char *s)
{
    size_t n = 0;

    for (; *s != '\0'; s++)
        n++;
    return n;
}
```

Searching for the End of a String (cont.)

- The condition `*s != '\0'` is the **same as** `*s != 0`, which in turn is the **same as** `*s`.
- A version of `strlen` that uses these observations:

```
size_t strlen(const char *s)
{
    size_t n = 0;
    for (; *s; s++)
        n++;
    return n;
}
```

`for (; *s++;)`

`while (*s++)`

Searching for the End of a String (cont.)

- Although we've condensed `strlen` quite a bit, it's likely that **we haven't increased its speed**.
- A version that **does run faster**, at least with some compilers:

```
size_t strlen(const char *s)
{
    const char *p = s;

    while (*s)
        s++;

    return s - p;
}
```


Searching for the End of a String (cont.)

- Idioms for “search for the null character at the end of a string”:

```
while (*s)
    s++;
```

```
while (*s++)
    ;
```

- The first version leaves `s` pointing to the null character.
- The second version is more concise, but leaves `s` pointing just past the null character.

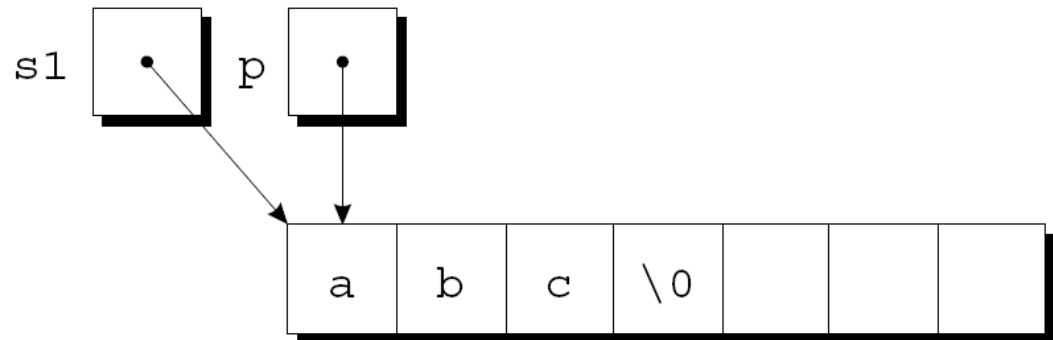
Copying a String

- Copying a string is another common operation.
- To introduce C's "string copy" idiom, we'll develop **two versions of the `strcat`** function.
- The **first version** of `strcat` (next slide) uses a **two-step algorithm**:
 - **Locate the null character at the end** of the string `s1` and make `p` point to it.
 - **Copy characters one by one from `s2` to** where `p` is pointing.

Copying a String (cont.)

```
char *strcat(char *s1, const char *s2)
{
    char *p = s1;
    while (*p != '\0')
        p++;
    while (*s2 != '\0') {
        *p = *s2;
        p++;
        s2++;
    }
    *p = '\0';
    return s1;
}
```

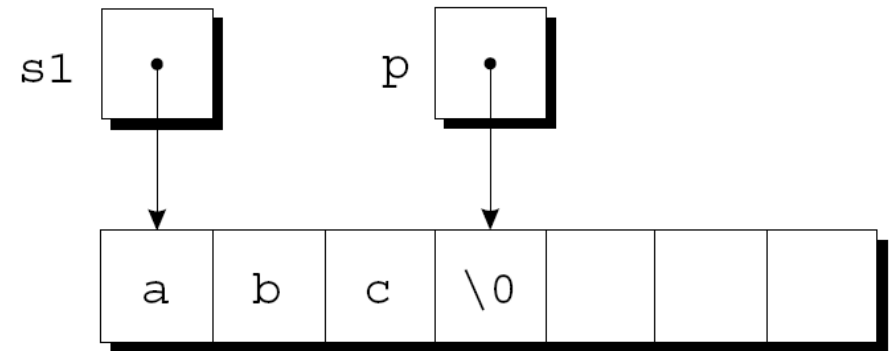
- **p initially points to the first character in the s1 string:**



Copying a String (cont.)

```
char *strcat(char *s1, const char *s2)
{
    char *p = s1;
    while (*p != '\0')
        p++;
    while (*s2 != '\0') {
        *p = *s2;
        p++;
        s2++;
    }
    *p = '\0';
    return s1;
}
```

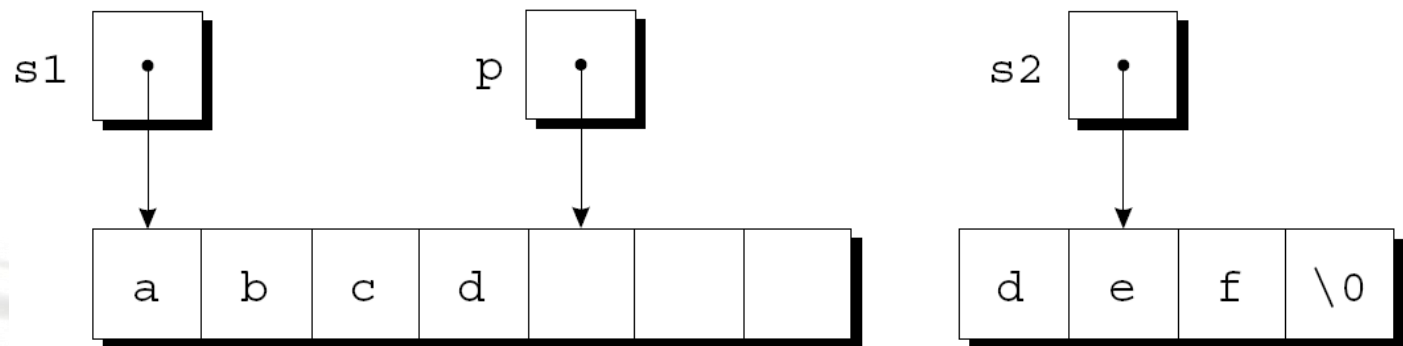
- The first while statement **locates the null character** at the end of s1 and makes p point to it:



Copying a String (cont.)

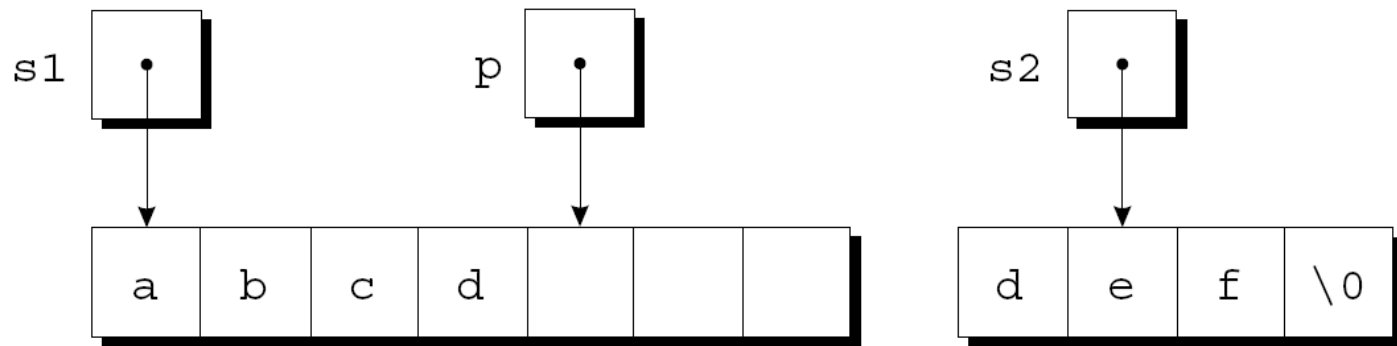
```
char *strcat(char *s1, const char *s2)
{
    char *p = s1;
    while (*p != '\0')
        p++;
    while (*s2 != '\0') {
        *p = *s2;
        p++;
        s2++;
    }
    *p = '\0';
    return s1;
}
```

- The second while statement **repeatedly copies one character from** where **s2** points to where **p** points, then **increments both p and s2**.

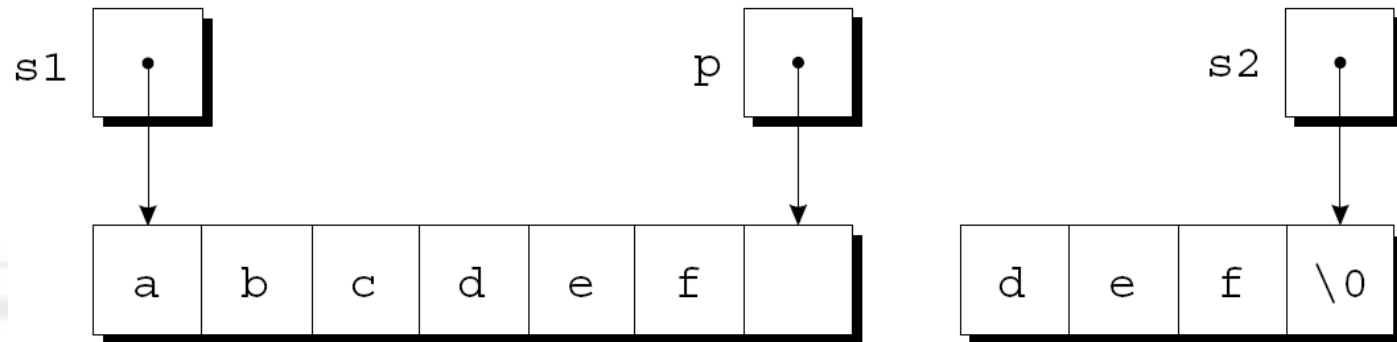


Copying a String (cont.)

- Assume that `s2` originally points to the string "def".
- The strings after the first loop iteration:



- The loop terminates when `s2` points to the null character:



Copying a String (cont.)

```
char *strcat(char *s1, const char *s2)
{
    char *p = s1;
    while (*p != '\0')
        p++;
    while (*s2 != '\0') {
        *p = *s2;
        p++;
        s2++;
    }
    *p = '\0';
    return s1;
}
```

- After **putting a null character** where `p` is pointing, `strcat` returns.

Copying a String (cont.)

- Condensed version of `strcat`:

```
char *strcat(char *s1,  
             const char *s2)
```

```
{
```

```
    char *p = s1;
```

```
    while (*p)
```

```
        p++;
```

```
    while (*p++ = *s2++)
```

```
        ;
```

```
    return s1;
```

```
}
```

```
char *strcat(char *s1,  
             const char *s2)
```

```
{
```

```
    char *p = s1;
```

```
    while (*p != '\0')
```

```
        p++;
```

```
    while (*s2 != '\0') {
```

```
        *p = *s2;
```

```
        p++;
```

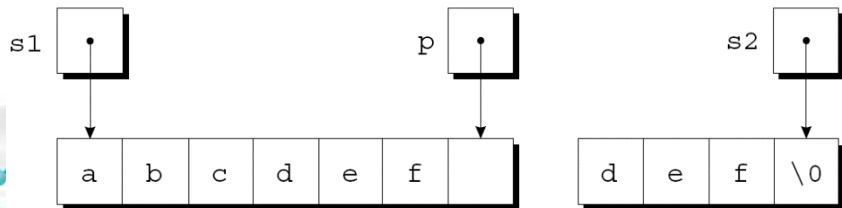
```
        s2++;
```

```
    }
```

```
    *p = '\0';
```

```
    return s1;
```

```
}
```



Copying a String (cont.)

- The heart of the streamlined `strcat` function is the “string copy” idiom:

```
while (*p++ = *s2++)  
    ;
```

- Ignoring the two `++` operators, the expression inside the parentheses is an assignment:

```
*p = *s2
```

- After the assignment, `p` and `s2` are incremented.
- Repeatedly evaluating this expression copies characters from where `s2` points to where `p` points.

Copying a String (cont.)

- But **what causes the loop to terminate?**
- The **while** statement tests the character that was **copied by** the assignment `*p = *s2`.
- **All characters except the null character test true.**
- The loop terminates *after* the assignment, so **the null character will be copied.**

Arrays of Strings

- There is **more than one way** to store an array of **strings**.
- One option is to use **a two-dimensional array of characters**, with one string per row:

```
char planets[][8] = {"Mercury", "Venus", "Earth",  
                    "Mars", "Jupiter", "Saturn",  
                    "Uranus", "Neptune", "Pluto"};
```

- The **number of rows** in the array **can be omitted**, but we **must specify the number of columns**.

Arrays of Strings (cont.)

- Unfortunately, the `planets` array contains a fair bit of wasted space (extra null characters):

	0	1	2	3	4	5	6	7
0	M	e	r	c	u	r	y	\0
1	V	e	n	u	s	\0	\0	\0
2	E	a	r	t	h	\0	\0	\0
3	M	a	r	s	\0	\0	\0	\0
4	J	u	p	i	t	e	r	\0
5	S	a	t	u	r	n	\0	\0
6	U	r	a	n	u	s	\0	\0
7	N	e	p	t	u	n	e	\0
8	P	l	u	t	o	\0	\0	\0

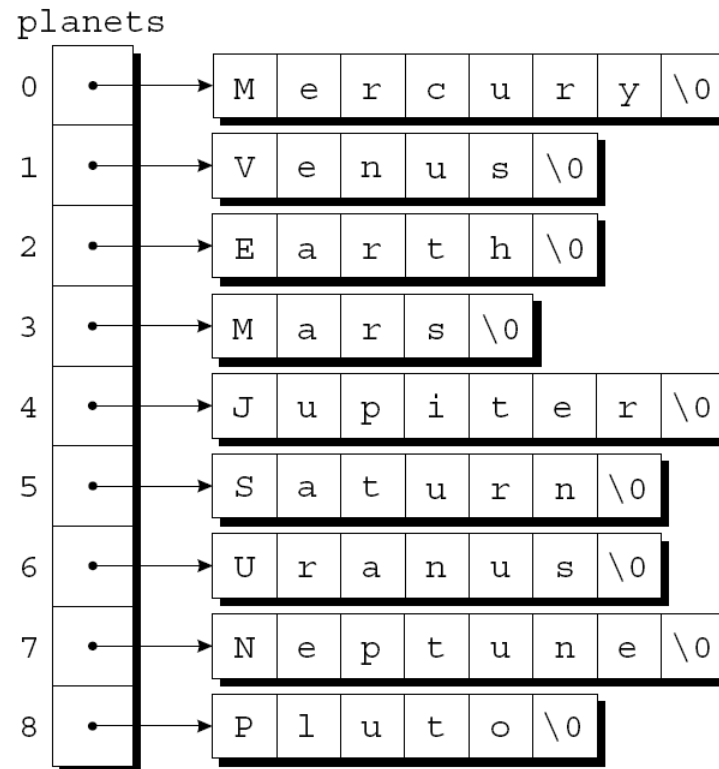
Arrays of Strings (cont.)

- Most collections of strings will have a mixture of long strings and short strings.
- What we need is a **ragged array**, whose rows can have different lengths.
- We can simulate a ragged array in C by creating an array whose elements are **pointers to strings**:

```
char *planets[] = {"Mercury", "Venus", "Earth",  
                  "Mars", "Jupiter", "Saturn",  
                  "Uranus", "Neptune", "Pluto"};
```

Arrays of Strings (cont.)

- This small change has a dramatic effect on how `planets` is stored:



Arrays of Strings (cont.)

- To access one of the planet names, all we need do is subscript the `planets` array.
- Accessing a character in a planet name is done in the same way as accessing an element of a two-dimensional array.
- A loop that searches the `planets` array for strings beginning with the letter M:

```
for (i = 0; i < 9; i++)  
    if (planets[i][0] == 'M')  
        printf("%s begins with M\n", planets[i]);
```

Command-Line Arguments

- When we run a program, we'll often need to supply it with information.
- This may include a file name or a switch that modifies the program's behavior.
- Examples of the UNIX `ls` command:

```
ls
```

```
ls -l
```

```
ls -l remind.c
```


Command-Line Arguments (cont.)

- Command-line information is available to all programs, not just operating system commands.
- To obtain access to **command-line arguments**, `main` must have two parameters:

```
int main(int argc, char *argv[])  
{  
    ...  
}
```

- Command-line arguments are called **program parameters** in the C standard.

Command-Line Arguments (cont.)

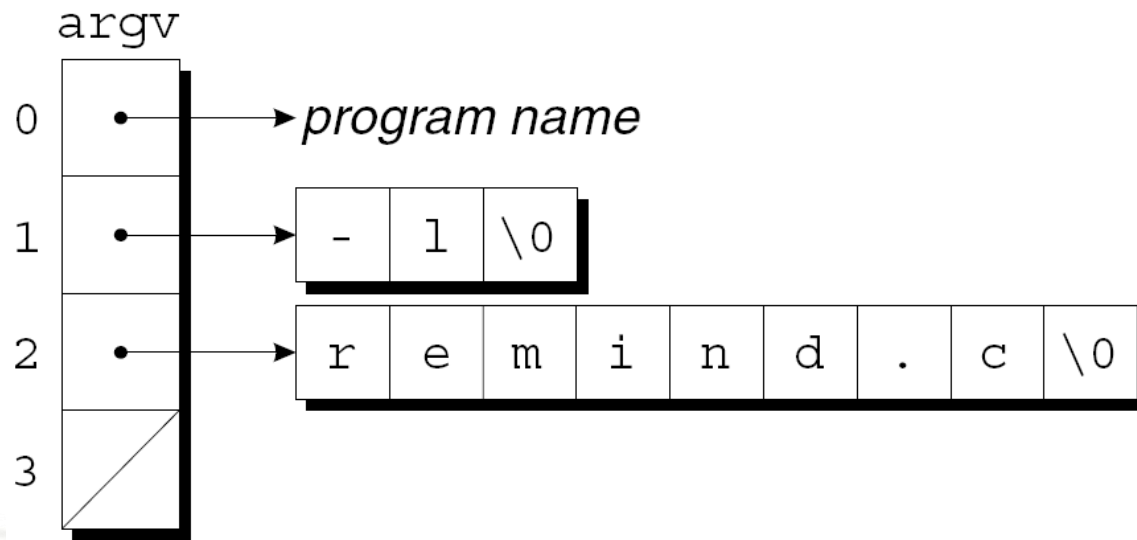
- `argc` ("argument count") is the number of command-line arguments.
- `argv` ("argument vector") is an array of pointers to the command-line arguments (stored as strings).
- `argv[0]` points to the name of the program, while `argv[1]` through `argv[argc-1]` point to the remaining command-line arguments.
- `argv[argc]` is always a **null pointer**—a special pointer that points to nothing.
 - The macro `NULL` represents a null pointer.

Command-Line Arguments (cont.)

- If the user enters the command line

```
ls -l remind.c
```

then `argc` will be **3**, and `argv` will have the following appearance:



Command-Line Arguments (cont.)

- Typically, a program that expects command-line arguments will set up a loop that examines each argument in turn.
- One way to write such a loop is to use an integer variable as an index into the `argv` array:

```
int i;  
for (i = 1; i < argc; i++)  
    printf("%s\n", argv[i]);
```

- Another technique is to set up a pointer to `argv[1]`, then increment the pointer repeatedly:

```
char **p;  
for (p = &argv[1]; *p != NULL; p++)  
    printf("%s\n", *p);
```

Program: Checking Planet Names

- The `planet.c` program illustrates how to access command-line arguments.
- The program is designed to check a series of strings to see which ones are names of planets.
- The strings are put on the command line:
- The program will indicate whether each string is a planet name and, if it is, display the planet's number:

```
planet Jupiter venus Earth fred
```

```
Jupiter is planet 5  
venus is not a planet  
Earth is planet 3  
fred is not a planet
```

Program: Checking Planet Names (cont.)

planet.c

```
#include <stdio.h>
#include <string.h>
#define NUM_PLANETS 9
int main(int argc, char *argv[])
{
    char *planets[] = {"Mercury", "Venus", "Earth",
                       "Mars", "Jupiter", "Saturn",
                       "Uranus", "Neptune", "Pluto"};

    int i, j;
    for (i = 1; i < argc; i++) {
        for (j = 0; j < NUM_PLANETS; j++)
            if (strcmp(argv[i], planets[j]) == 0) {
                printf("%s is planet %d\n", argv[i], j + 1);
                break;
            }
        if (j == NUM_PLANETS)
            printf("%s is not a planet\n", argv[i]);
    }

    return 0;
}
```