Week 4 - Lecture 1, 2

Pointers

Edited by: Dr. Wooi Ping Cheah

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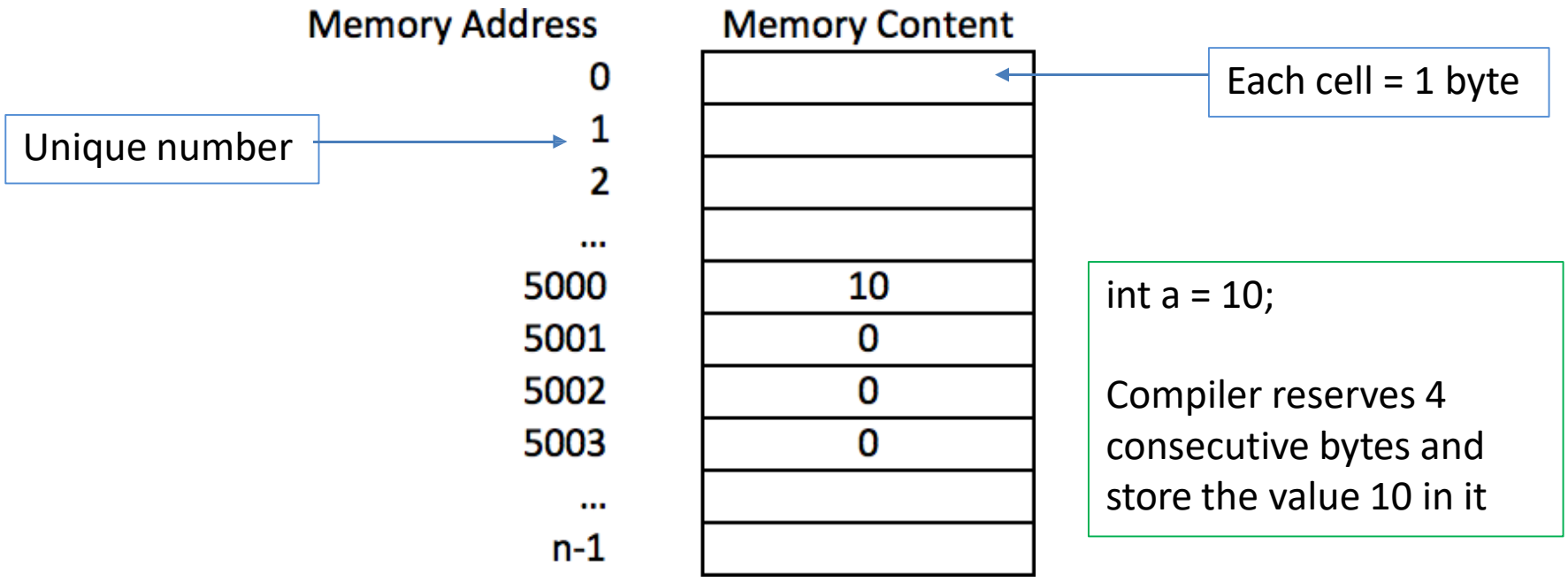
University of Nottingham
UK | CHINA | MALAYSIA

Overview

- Declaration and initialisation
- Pointer to Constant vs. const Pointer
- Pointers and arrays
  - String literals
- Array of pointers
- Pointer arithmetic (e.g. subtracting, comparing)

Memory Layout



Var Name, Val and Mem Address

- int ID = 2017233;

Variable name

Value

- &ID

Memory address of ID

```
C:\Users\z2017233\Desktop>iteration
Current ID number is 0
Current ID number is 0060FF2C


Enter your ID number: 2017233


Current ID number is 2017233
Current ID number is 0060FF2C

C:\Users\z2017233\Desktop>_
```

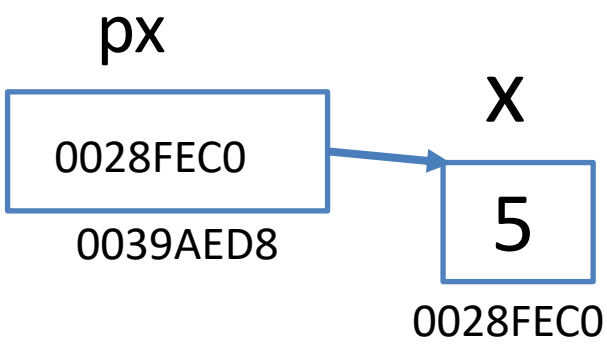
```
2   #include <stdio.h>
3
4   int main(void)
5   {
6       int id = 0;
7
8       printf("Current ID number is %d\n", id);
9       printf("Current ID number is %p\n", &id);
10
11      printf("\n\nEnter your ID number: ");
12      scanf("%d", &id);
13
14      printf("\n\nCurrent ID number is %d\n", id);
15      printf("Current ID number is %p\n", &id);
16
17      return 0;
18  }
```

Pointer and Variable

- Pointers are variables whose values are memory addresses.
- Pointers enable programs to:
  - simulate pass-by-reference
  - pass functions between functions
  - create and manipulate dynamic data structures, i.e., data structures that can grow and shrink at execution time, such as linked lists, queues, stacks and trees.

Pointer and Variable (2)

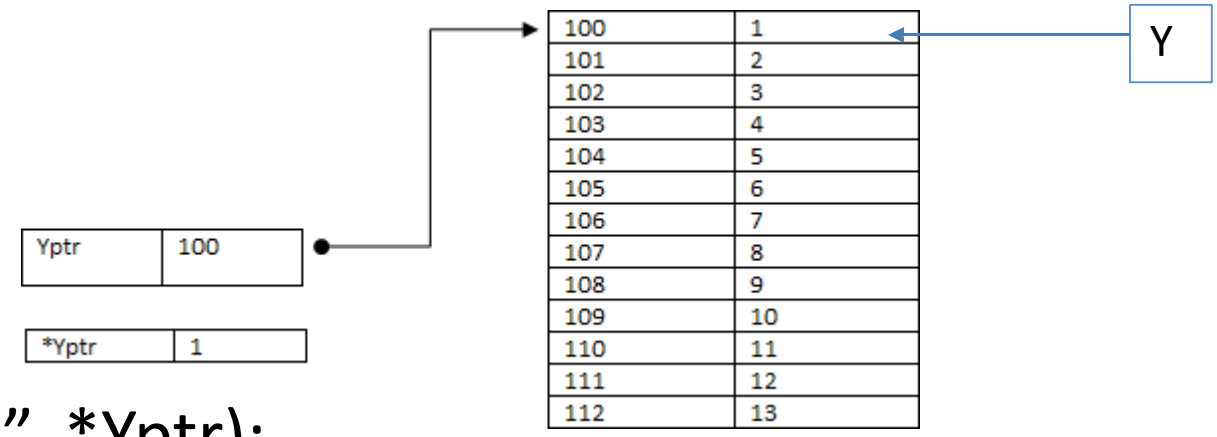
```
// normal integer initialised to value 5
int x = 5;
// declare a pointer to an integer variable
int *px;
// set the pointer value to the address of the
x variable
px = &x;
```



Pointer and Variable (3)

- A variable name *directly* references a value, a pointer ***indirectly*** references a value.

```
int Y = 1;
int *Yptr;
Yptr = &Y;
```




```
printf("%d\n", *Yptr);
          ||
printf("%d\n", Y);
```

Source: http://www.exforsys.com/tutorials/c-language/c-pointers.html

Pointer and Variable (4)

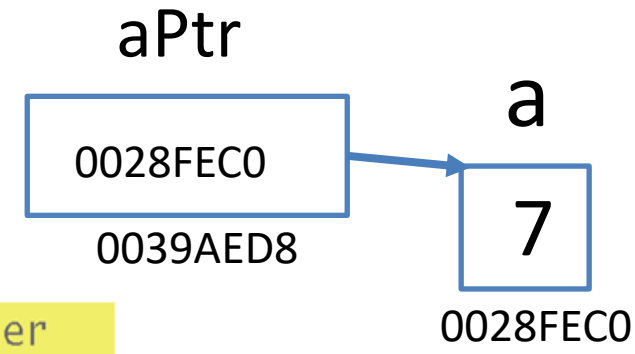
- A pointer may be initialized to NULL, 0 or an address.
- A pointer with the value NULL points to nothing.

```
int *px = NULL;
// ...
// do some things that may or may not
// make px point to a variable.
// ...
if(px != NULL)
{
   printf("%d\n", *px);
}
```

Example: a simple pointer

```
1  // Fig. 7.4: fig07_04.c
2  // Using the & and * pointer operators.
3  #include <stdio.h>
4
5  int main( void )
6  {
7     int a; // a is an integer
8     int *aPtr; // aPtr is a pointer to an integer
9
10    a = 7;
11    aPtr = &a; // set aPtr to the address of a
12
13    printf( "The address of a is %p"
14            "\nThe value of aPtr is %p", &a, aPtr );
15
16    printf( "\n\nThe value of a is %d"
17            "\nThe value of *aPtr is %d", a, *aPtr );
18
19    printf( "\n\nShowing that * and & are complements of "
20            "each other\n&*aPtr = %p"
21            "\n*&aPtr = %p\n", &*aPtr, *&aPtr );
22 } // end main
```

```c
// Fig. 7.4: fig07_04.c
// Using the & and * pointer operators.
#include <stdio.h>

int main( void )
{
   int a; // a is an integer
   int *aPtr; // aPtr is a pointer to an integer

   a = 7;
   aPtr = &a; // set aPtr to the address of a

   printf( "The address of a is %p"
           "\nThe value of aPtr is %p", &a, aPtr );

   printf( "\n\nThe value of a is %d"
           "\nThe value of *aPtr is %d", a, *aPtr );

   printf( "\n\nShowing that * and & are complements of "
           "each other\n&*aPtr = %p"
           "\n*&aPtr = %p\n", &*aPtr, *&aPtr );
} // end main
```



&a == 0028FEC0

aPtr == 0028FEC0

a == 7

*aPtr == 7

&*aPtr == 0028FEC0

*&aPtr == 0028FEC0

Example (output)

```
The address of a is 0028FEC0
The value of aPtr is 0028FEC0

The value of a is 7
The value of *aPtr is 7

Showing that * and & are complements of each other
&*aPtr = 0028FEC0
*&aPtr = 0028FEC0
```

Declaring Pointers

- Pointers hold **memory address** of another variable
- **int** *int_ptr, myInt;
- **double** *double_ptr, myDouble;

the size of any pointer variable is 4 bytes
same as int

- sizeof(int_ptr) == sizeof(double_ptr) == sizeof(myInt) = 4 bytes
- sizeof(myDouble) = 8 bytes

Pointer Initialisation

- Memory address operator is &

- int *ptr;
  int a = 0;
  ptr = &a;

Careful!!, If pointer is used without initialisation, it can cause segmentation fault

- int *ptr = NULL;

Pointer that **does NOT** point to anything.

Example: Pointer and Variable

- int num = 50;
- int *ptr = #

- **Variable** **Value in it**
  num 50
  &num 1002
  ptr 1002
  *ptr 50

Source: http://www.c4learn.com/c-programming/c-dereferencing-pointer/

Example: Pointer and Variable (2)

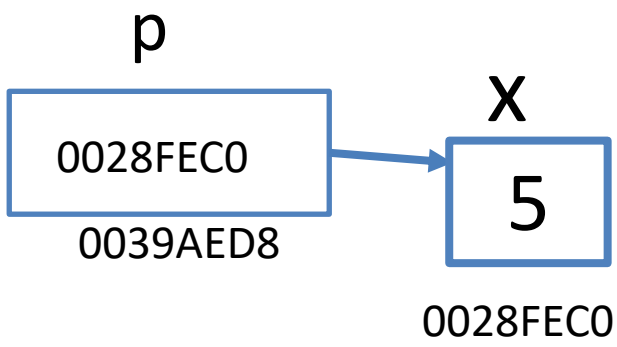
- Memory addresses are unchanged.
- Values can be changed.
  - For pointer, the change of value means the change of location (where it is pointing to).

De-referencing of Pointer

- To read the value at a given memory address

```
 99  int main(void)
100  {
101      int x = 5;
102      int *p = NULL;
103
104      p = &x;
105
106      printf("%d\n", *p); // dereference
107
108      printf("%p\n", &p);
109      printf("%p\n", p);
110      printf("%p\n", &x);
111
112      // NOTE: the output when printing out p and &x is the same because p is a pointer
113      //       and it is pointing to x, therefore memory address of x is sotred in p
114
115      return 0;
116  }
```

```c
int main(void)
{
    int x = 5;
    int *p = NULL;

    p = &x;

    printf("%d\n", *p); // dereference

    printf("%p\n", &p);
    printf("%p\n", p);
    printf("%p\n", &x);

    // NOTE: the output when printing out p and &x is the same because p is a pointer
    //       and it is pointing to x, therefore memory address of x is sotred in p

    return 0;
}
```



*p == 5

&p == 0039AED8

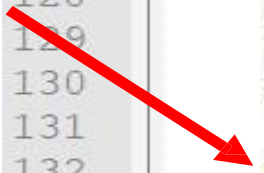
p == 0028FEC0

&x == 0028FEC0

De-referencing of Pointer (2)

- To write the value at a given memory address

```
121  int main(void)
122  {
123      int x = 5;
124      int *p = NULL;
125
126      p = &x;
127
128      printf("%d\n", *p); // dereference
129      printf("%p\n", p);
130      printf("x is %d\n", x);
131
132      *p = 7; // dereference
133      printf("\n%d\n", *p); // dereference
134      printf("%p\n", p);
135      printf("x is %d\n", x);
136
137
138      return 0;
139  }
```



Suggestions – Code Spacing

- Compile error

Example: good spacing

```
*average = *total / *count;    /* compute the average */
```

Example: poor spacing

```
*average=*total/*count;        /* compute the average */
                  ^ begin comment  end comment^
```

Q1: What is the output?

- int *ptr, a;
  a = 10;
  ptr = &a;
  printf("Val = %d\n", *ptr);

Val = 10

Memory Address	Memory Content
0	
1	
2	
...	
5000	10
5001	0
5002	0
5003	0
...	
n-1	

Q2: What is the output?

```
int *pc, c;
c = 5;
pc = &c;
c = 1;
printf("%d", c);
printf("%d", *pc);
```

```
1
1
```

Q3: What is the output?

```
int *pc, c, d;
c = 5;
d = -15;
pc = &c;
printf("%d", *pc);
pc = &d;
printf("%d", *pc);
```

```
5

-15
```

Q3: What is the output?

```
int *pc, c, d;
c = 5;
d = -15;
pc = &c;
printf("%d", *pc);
pc = &d;
printf("%d", *pc);
```

Q4: What is the output?

```
#include <stdio.h>
int main()
{
  int *pc, c;

  c = 22;
  printf("Address of c: %p\n", &c);
  printf("Value of c: %d\n\n", c);

  pc = &c;
  printf("Address of pointer pc: %p\n", pc);
  printf("Content of pointer pc: %d\n\n", *pc);

  c = 11;
  printf("Address of pointer pc: %p\n", pc);
  printf("Content of pointer pc: %d\n\n", *pc);

  *pc = 2;
  printf("Address of c: %p\n", &c);
  printf("Value of c: %d\n\n", c);
  return 0;
}
```

Q5: what is the output?

```
int i = 0, *ptr = &i;
*ptr = *ptr ? 10 : 20;
printf("Val = %d\n", i);
```

Q5: what is the output?

```
int i = 0, *ptr = &i;
*ptr = *ptr ? 10 : 20;
printf("Val = %d\n", i);
```

Q6: what is the output?

- int *ptr1, *ptr2, *ptr3, i = 10, j = 20, k = 30;
  ptr1 = &i;
  ptr2 = &j;
  ptr3 = &k;
  *ptr1 = *ptr2 = *ptr3;
  k = i+j;
  printf("%d\n", *ptr3); 60

Q6: what is the output?

- int *ptr1, *ptr2, *ptr3, i = 10, j = 20, k = 30;
  ptr1 = &i;
  ptr2 = &j;
  ptr3 = &k;
  *ptr1 = *ptr2 = *ptr3;
  k = i+j;
  printf("%d\n", *ptr3);

Q7: what is the output?

- int *ptr1, *ptr2, *ptr3, i = 10, j = 20, k = 30;
  ptr1 = &i;
  i = 100;
  ptr2 = &j;
  j = *ptr2 + *ptr1;
  ptr3 = &k;
  k = *ptr3 + *ptr2;
  printf("%d %d %d\n", *ptr1, *ptr2, *ptr3);

Q7: what is the output?

- int *ptr1, *ptr2, *ptr3, i = 10, j = 20, k = 30;
  ptr1 = &i;
  i = 100;
  ptr2 = &j;
  j = *ptr2 + *ptr1;
  ptr3 = &k;
  k = *ptr3 + *ptr2;
  printf("%d %d %d\n", *ptr1, *ptr2, *ptr3);

Overview

- Declaration and initialisation
- **Pointer to Constant vs. const Pointer**
- Pointers and arrays
  - String literals
- Array of pointers
- Pointer arithmetic (e.g. subtracting, comparing)

Pointer to a const Variable

- **A non-constant pointer to constant data can be modified to point to any data item of the appropriate type, but the data to which it points cannot be modified.**
  - Such a pointer might be used to receive an array argument to a function that will process each element without modifying the data.

Pointer to a const Variable (2)

- Here, pointer can be used to change the data.

```
160  #include <stdio.h>
161
162  int main(void)
163  {
164      const int x = 5, y = 6;
165      int *p = &x;
166
167      printf("de-p is %d\n", *p); // dereference
168      printf("x is %d\n", x);
169      printf("y is %d\n", y);
170
171      //x = 7;
172      *p = 7;
173      printf("\n\nde-p is %d\n", *p); // dereference
174      printf("x is %d\n", x);
175      printf("y is %d\n", y);
176
177      p = &y;
178      printf("\n\nde-p is %d\n", *p); // dereference
179      printf("x is %d\n", x);
180      printf("y is %d\n", y);
181
182
183      return 0;
184  }
```

Declaring pointer to ordinary int variable, and initialising it.

A loophole to change the value of constant variable x.

“Pointer to Constant” to const Var

- Here, **compile error**!!
- Pointer to constant can NOT be used to change data.

```
187  #include <stdio.h>
188
189  int main(void)
190  {
191      const int x = 5, y = 6;
192      const int *p = &x;
193
194      printf("de-p is %d\n", *p); // dereference
195      printf("x is %d\n", x);
196      printf("y is %d\n", y);
197
198      //x = 7;
199      *p = 7;
200      printf("\n\nde-p is %d\n", *p); // dereference
201      printf("x is %d\n", x);
202      printf("y is %d\n", y);
203
204      p = &y;
205      printf("\n\nde-p is %d\n", *p); // dereference
206      printf("x is %d\n", x);
207      printf("y is %d\n", y);
208
209
210      return 0;
211  }
```

“Pointer to Constant” to non-const Var

- Prohibits to change the value of a variable through a “pointer to constant”.

- int j, i = 10;
  const int *ptr;
  ptr = &i;

Allowed: “pointer to constant” points to a non-constant variable.

- *ptr = 30;

Not allowed: the program won’t compile

const Pointer to constant Var

- The least access privilege is granted by a constant pointer to constant data.
- Such a pointer always points to the same memory location, and the data at that memory location cannot be modified.

const Pointer to constant Var (2)

- Prohibits a pointer from **pointing to another variable**

- const int j=20, i = 10;
  int *const ptr = &i;
  *ptr = 30;

A loophole to change the value of constant variable i.

- ptr = &j;

Not allowed: the programme won't compile

const Pointer to non-constant Var

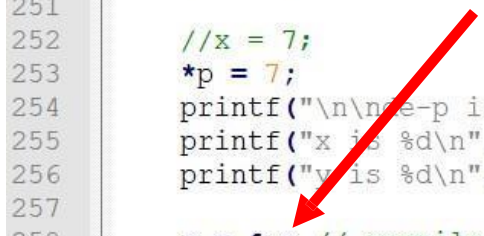
- A constant pointer to non-constant data always points to the same memory location, and the data at that location can be modified through the pointer.

- Pointers that are declared “const” must be initialized when they’re defined.

const Pointer to non-constant Var (2)

- Here, **compile error**!!
- const Pointer can NOT change where it is pointed to.

```
241  #include <stdio.h>
242
243  int main(void)
244  {
245      int x = 5, y = 6;
246      int *const p = &x;
247
248      printf("de-p is %d\n", *p); // dereference
249      printf("x is %d\n", x);
250      printf("y is %d\n", y);
251
252      //x = 7;
253      *p = 7;
254      printf("\n\nde-p is %d\n", *p); // dereference
255      printf("x is %d\n", x);
256      printf("y is %d\n", y);
257
258      p = &y; // compile error
259      printf("\n\nde-p is %d\n", *p); // dereference
260      printf("x is %d\n", x);
261      printf("y is %d\n", y);
262
263
264      return 0;
265  }
```



Pointer to Constant vs. const Pointer

- Pointer to Constant
  `const int* ptr = &x;`

  const Pointer
  `int *const ptr = &x;`

  Variable it is pointed to:

  can be modified
  e.g. `ptr = &y;`

  CANNOT

  Value pointed by the pointer:

  CANNOT

  can be modified
  e.g. `*ptr = 7;`

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  - **String literals**
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- Pointer arithmetic (e.g. subtracting, comparing)

Pointers and Arrays

- The elements of an array are stored in successive memory location
- int arr[2];
- The first element is stored in 5000 – 5003
- The second element is stored in 5004 – 5007
- arr == &arr[0]

Memory Address	Memory Content
0	
1	
2	
...	
5000	10
5001	0
5002	0
5003	0
...	
n-1	

Name of an array can be used as a pointer to its first element!!

Use Pointer Variable like Array

Name of an array can be used as a pointer to its first element!!

- int *ptr, i, arr[5] = {10, 20, 30, 40, 50};

```
ptr = arr;

for(i = 0; i < 5; i++){
      printf("Addr = %p Val = %d\n", ptr, *ptr);
      ptr++;
}
```

Points to the first element 10

Increment the pointer by 4 bytes
WHY?!

Address and value

it means that the ptr go to the next location
but it does not mean that the byte plus 1

Pointer to Array

- How many of the printfs below have the same output?

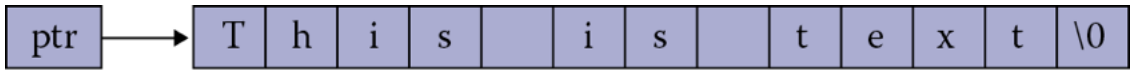
```
299     int x[] = {9, 11, 13};
300     int *p;
301     p = x; // array name is a pointer, and pointer stores memory address!!
302
303     int y = 10;
304     int *q;
305     q = &y; // note the difference when pointer is pointing to an array
306             // and when pointer is pointing to a normal variable
307
308     printf("%p\n", x);
309     printf("%p\n", &x[0]);
310     printf("%p\n", p);
311     printf("%p\n", &p);
```

```
19035@CSLinux PGA-w4l1]$ ./ex7
fe7e971dd0
fe7e971dd0
fe7e971dd0
fe7e971dc8
19035@CSLinux PGA-w4l1]$
```

Pointers and String Literals

- printf(“%c %c\n”, “message”[4], *(“message”+4));

- char *ptr = “This is text”;



String literals is usually read-only, so you might not be able to modify its content

- printf("%c %c\n", ptr[5], *(ptr+5));
  printf("%s\n", ptr);
  printf("%s\n", ptr+5);

```
C:\Users\z2017233\Desktop>ptr
a a
i i
This is text
is text
```

Example: Your own strlen

- Relies on having '\0' to terminate your string.
- Otherwise, undefined behaviour.

```c
#include <stdio.h>

int main(void)
{
    // Can declare your string as char *
    // The const keyword enforces the fact you are not allowed to change
    // a string literal.
    // const char *str = "Paul";

    // Or you could declare the string as an array of characters.
    // Try changing the nul character at the end to something else to see
    // what happens with string not ending in \0.
    char name[] = {'P','a','u','l','\0'};
    char *str = name;  // "name" equivalent to "&name[0]"

    // First version that uses array notation.
    int n = 0;
    while(str[n] != '\0')
    {
        //printf("%c", str[n]);  // Comment out to print characters 1 by 1
                                 // while counting.
        n = n + 1;
    }
    printf("\nArray notation length %d.\n", n);

    // Second version that uses pointer arithmetic.
    int len = 0;
    while(*str != '\0')
    {
        //printf("%c", *str);  // Comment out to print characters 1 by 1
                               // while counting.
        str = str + 1;
        len = len + 1;
    }
    printf("\nPointer arithmetic length %d.\n", len);

    return 0;
}
```

```c
#include <stdio.h>

int main(void)
{
    // Can declare your string as char *
    // The const keyword enforces the fact you are not allowed to change
    // a string literal.
    // const char *str = "Paul";

    // Or you could declare the string as an array of characters.
    // Try changing the nul character at the end to something else to see
    // what happens with string not ending in \0.
    char name[] = {'P','a','u','l','\0'};
    char *str = name;  // "name" equivalent to "&name[0]"

    // First version that uses array notation.
    int n = 0;
    while(str[n] != '\0')
    {
        //printf("%c", str[n]);  // Comment out to print characters 1 by 1
                                 // while counting.
        n = n + 1;
    }
    printf("\nArray notation length %d.\n", n);

    // Second version that uses pointer arithmetic.
    int len = 0;
    while(*str != '\0')
    {
        //printf("%c", *str);  // Comment out to print characters 1 by 1
                               // while counting.
        str = str + 1;
        len = len + 1;
    }
    printf("\nPointer arithmetic length %d.\n", len);

    return 0;
}
```

String Functions

- #include <string.h>
- strlen() – not counting null character
- strcpy(*dest, *src)
- strncpy(*dest, *src, count)
- strcat(*dest, *src)
- strcmp(*dest, *src)
- strncmp(*dest, *src, count)

Check if dest is big enough!!

Add null character if src is shorter than count

Negative for less or shorter, positive for more, zero for identical

Read more here: https://beginnersbook.com/2014/01/c-strings-string-functions/

Q8: What will be displayed?

- int *ptr, arr[5] = {10, 20, 30, 40, 50}; ptr = arr;

  printf("Val1 = %d, Val2 = %d\n", *ptr+2,*(ptr+2));

Q9: What is arr[0] + arr[2]?

- int *ptr, arr[] = {10, 20, 30, 40, 50};
  ptr = arr;
  *ptr = 3;
  ptr += 2;
  *ptr = 5;
  printf("Val = %d\n", arr[0]+arr[2]);

Summary

- Declaration and initialisation
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  - String literals