Week 4- lecture 1, 2

Pointers

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https://www.vectorstock.com/royalty-free-vector/smiling-donkey-head-vector-1217480

Quiz!

Which one is True?

A) Binary search is more complicated than linear.

B) Linear search works only for numbers, but not character.

C) Bubble sort and selection sort work with no iteration.

D) Bubble and selection only sort the value ascending.

Quiz!

Which one is True?

A) Binary search is more complicated than linear.

B) Linear search works only for numbers, but not character.

C) Bubble sort and selection sort work with no iteration.

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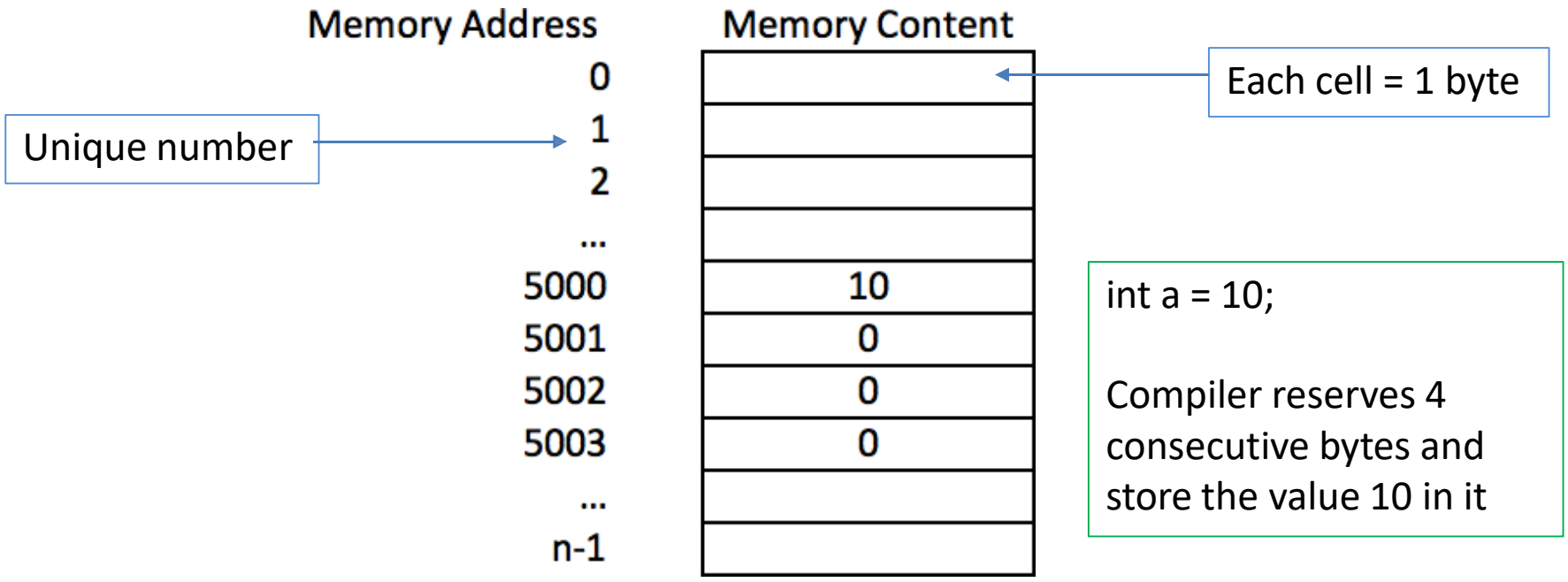
Overview

- 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

Analogy:

StudentA received a 1st class degree.

StudentA lives in Building #23.

```
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.

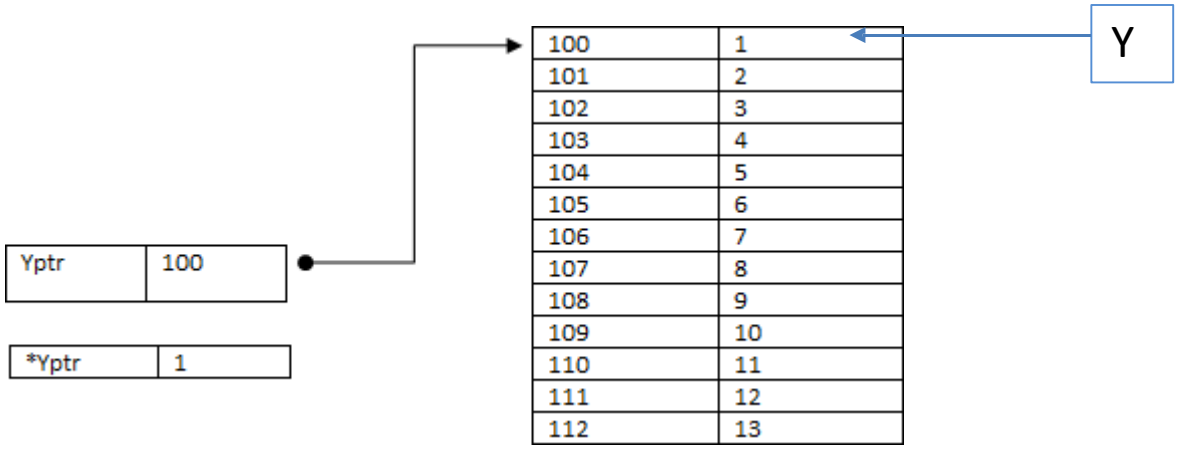
Pointer and Variable (2)

```
// 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;
```



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
```

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;

- 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  }
```

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 */
```

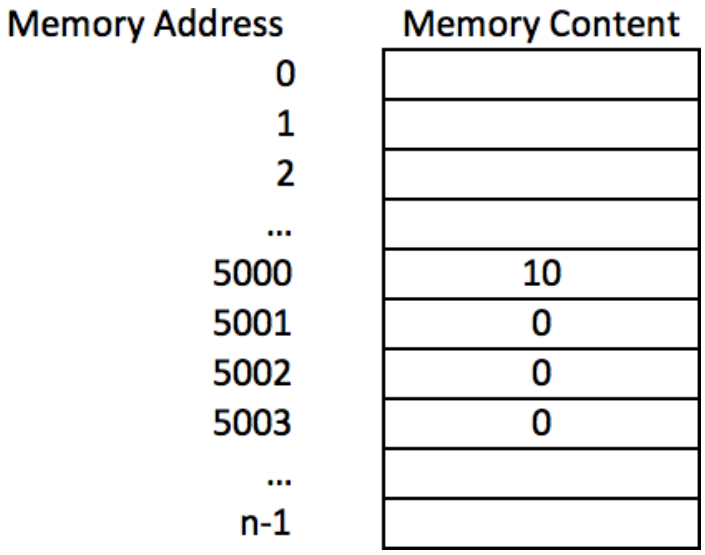
Example: poor spacing

```
*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);

a) 5000
b) 10
c) 5003
d) 5010



Q1: What is the output?

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

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

a) 5000
b) 10
c) 5003
d) 5010

Q2: What is the output?

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

a) 5, 1

b) 1, 1

c) 5, 5

d) 1, 5

Q2: What is the output?

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

a) 5, 1

b) 1, 1

c) 5, 5

d) 1, 5

Q3: What is the output?

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

a) 5, -15
b) -15, 5
c) 5, 5
d) -15, -15

Q3: What is the output?

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

a) 5, -15
b) -15, 5
c) 5, 5
d) -15, -15

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;
}
```

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;
}
```

Address of c: 2686784
Value of c: 22

Address of pointer pc: 2686784
Content of pointer pc: 22

Address of pointer pc: 2686784
Content of pointer pc: 11

Address of c: 2686784
Value of c: 2

Q5: what is the output?

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

a) 10
b) 0
c) 455839228 (a mem addr)
d) 20

Q5: what is the output?

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

a) 10
b) 0
c) 455839228 (a mem addr)
d) 20

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);

a) 20
b) 30
c) 50
d) 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);

a) 20
b) 30
c) 50
d) 60

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);

a) 100, 120, 150
b) 100, 150, 120
c) 110, 110, 130
d) 110, 130, 110

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);

a) 100, 120, 150
b) 100, 150, 120
c) 110, 110, 130
d) 110, 130, 110

Overview

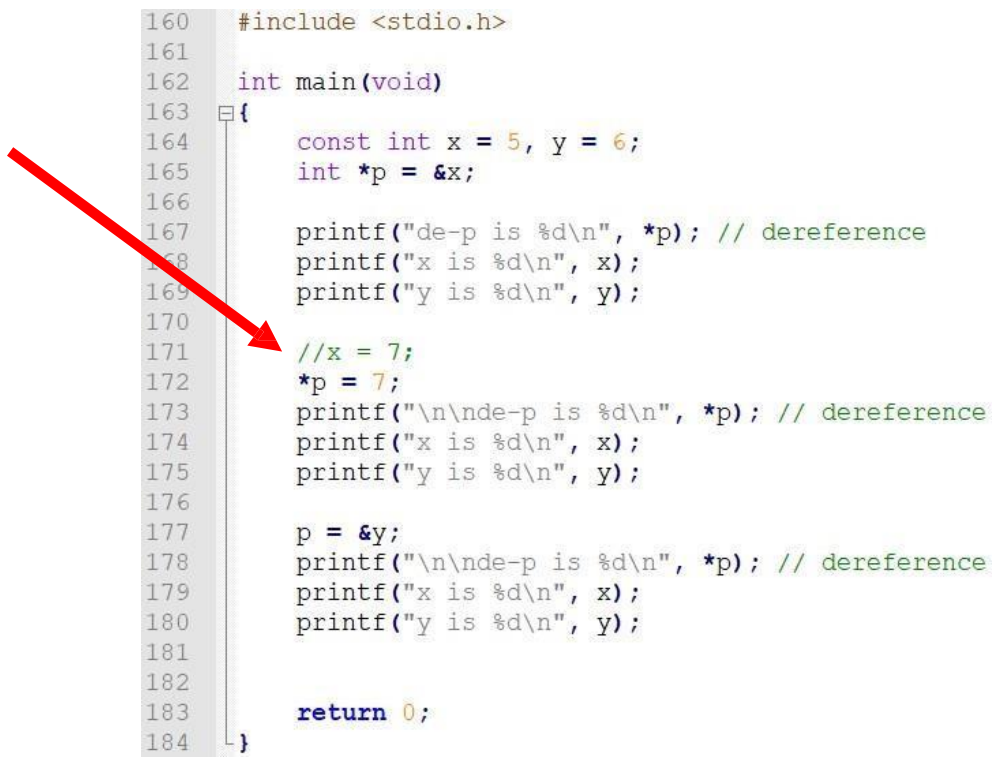
- Declaration and initialisation
- **Pointer to Constant vs. const Pointer**
- Pointers and arrays
  - String literals
- Array of pointers
- Pointer arithmetic (e.g. subtracting, comparing)

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.



```c
#include <stdio.h>

int main(void)
{
    const int x = 5, y = 6;
    int *p = &x;

    printf("de-p is %d\n", *p); // dereference
    printf("x is %d\n", x);
    printf("y is %d\n", y);

    //x = 7;
    *p = 7;
    printf("\n\nde-p is %d\n", *p); // dereference
    printf("x is %d\n", x);
    printf("y is %d\n", y);

    p = &y;
    printf("\n\nde-p is %d\n", *p); // dereference
    printf("x is %d\n", x);
    printf("y is %d\n", y);


    return 0;
}
```

“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  }
```

Constant 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)

- Prohibits a pointer from changing **the value of the variable** it points to

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

- *ptr = 30;

Not allowed: the programme won't compile

const Pointer to non-constant Var (3)

- 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;

Constant 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.

Constant 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;

- ptr = &j;

Overview

- Declaration and initialisation
- Pointer to Constant vs. const Pointer
- **Pointers and arrays**
  - **String literals**
- Array of pointers
- 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

- 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

Increment the pointer by 4 bytes
WHY?!

Address and value

Pointer to Array

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

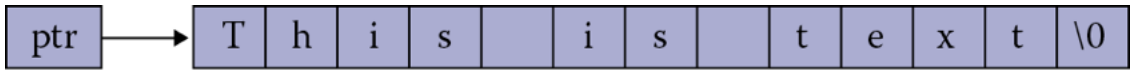
```
299     int x[] = {9, 11, 13};
300     int *p;
301     p = x; // array name is a pointer, and pointer stores memory address!!
302
303     int y = 10;
304     int *q;
305     q = &y; // note the difference when pointer is pointing to an array
306             // and when pointer is pointing to a normal 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;
}
```

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));

a) Val1 = 22, Val2= 20
b) Val1 = 22, Val2= 30
c) Val1 = 12, Val2= 20
d) Val1 = 12, Val2= 30

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));

a) Val1 = 22, Val2= 20
b) Val1 = 22, Val2= 30
c) Val1 = 12, Val2= 20
d) Val1 = 12, Val2= 30

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]);

  a) 10
  b) 30
  c) 40
  d) 8

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]);

  a) 10
  b) 30
  c) 40
  d) 8

Summary

- Declaration and initialisation
- Pointer to Constant vs. const Pointer
- Pointers and arrays
  - String literals

Quiz

What is the output?

- ```
  int *ptr1, *ptr2, i = 10, j = 20;
  ptr1 = &i;
  ptr2 = &j;
  ptr2 = ptr1;
  *ptr1 = *ptr1 + *ptr2;
  *ptr2 = 2*(*ptr2);
  printf("Val = %d\n", *ptr1 + *ptr2);
  ```

a) 80
b) 60
c) 40
d) 20
  ```

Quiz

What is the output?

- ```
  int *ptr1, *ptr2, i = 10, j = 20;
  ptr1 = &i;
  ptr2 = &j;
  ptr2 = ptr1;
  *ptr1 = *ptr1 + *ptr2;
  *ptr2 = 2*(*ptr2);
  printf("Val = %d\n", *ptr1 + *ptr2);
  ```

a) 80
b) 60
c) 40
d) 20
  ```