Introduction to Programming

C – Arrays, Pointers, Dynamic Memory Allocation

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What is an array?

	$A[0]$	$A[1]$	$A[2]$	...	$A[n-1]$
A	At xxxx	At xxxx+b	At xxxx+2b	...	At xxxx+(n-1)b

What is an array?

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- Sequence of n *contiguous* memory locations
- *Length* of the array $= n$
- *Elements* of the array can be mapped to each of the n memory locations
- Elements numbered 0 through $n-1$

What is an array?

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- *Length* of the array $= n$
- *Elements* of the array can be mapped to each of the n memory locations
- Elements numbered 0 through $n-1$

```
char charArray[100], c;
charArray[i] = c;          // 0 <= i <= 99
int intArray[20], i, j;
intArray[0] = i;
j = intArray[19];
```

Multi-dimensional arrays

	At xxxx	At xxxx+b	At xxxx+2b	...	At xxxx+(n-1)b
A	$A[0][0]$	$A[0][1]$	$A[0][2]$	...	$A[0][n-1]$
	$A[1][0]$	$A[1][1]$	$A[1][2]$	...	$A[1][n-1]$
	At xxxx+nb	At xxxx+(n+1)b	At xxxx+(n+2)b	...	At xxxx+(2n-1)b

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- Sequence of $m \times n$ *contiguous* memory locations
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- Sequence of $m \times n$ *contiguous* memory locations
- *Elements* of the array can be mapped to each of the $m \times n$ memory locations

```
char charArray[10][20], c;
charArray[i][j] = c;          // 0 <= i <= 9, 0 <= j <= 19
int intArray[10][20], i, j;
intArray[0][0] = i;
j = intArray[9][19];
```

Multi-dimensional arrays

Providing the size is optional if a one-dimensional array is initialized while declaration takes place.

```
int charArray[] = {'a', 'b', 'c', 'd', 'e', 'f'};
int intArray[] = {1, 2, 3, 4, 5, 6};
```

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Providing the size is optional if a one-dimensional array is initialized while declaration takes place.

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int charArray[] = {'a', 'b', 'c', 'd', 'e', 'f'};
int intArray[] = {1, 2, 3, 4, 5, 6};
```

For multi-dimensional arrays, the following scenarios will work:

```
int intArray1[2][3] = {1, 2, 3, 4, 5, 6};
int intArray2[][3] = {1, 2, 3, 4, 5, 6};
```

However, the following will not work:

```
int intArray3[2][] = {1, 2, 3, 4, 5, 6};
int intArray4[][] = {1, 2, 3, 4, 5, 6};
```

Strings

Definition

Strings are character arrays but the end of a string is marked by the first occurrence of '\0' in the array (not the last element of the array)

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Example:

```
char Alphabet[26];
Alphabet[0] = 'A'; Alphabet[1] = 'B'; Alphabet[2] = 'C';
Alphabet[3] = '\0'; // NOT '0'
/* Alphabet now holds the string "ABC" */
```

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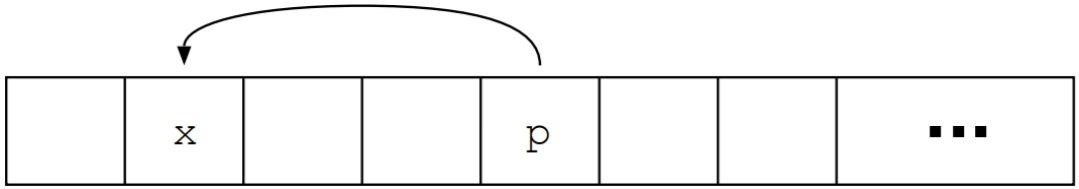
```

'A'	'B'	'C'	'\0'		

The fourth cell ends the string but it is not the end of the array

Pointers

- Memory = consecutively numbered storage cells (*bytes*)
- Variable can occupy one or more bytes
- *Address* of a variable = serial number of "first" byte occupied by the variable
- *Pointer* holds the address of a variable



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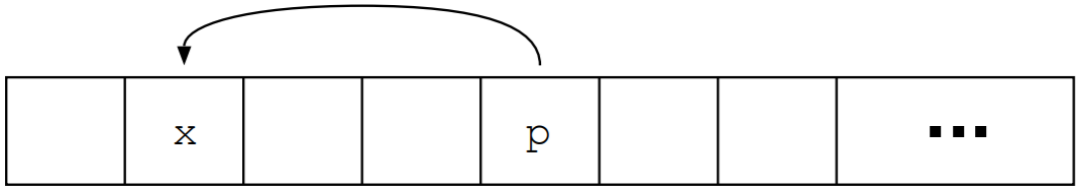

Note: A *pointer* variable (whatever be it pointing to) occupies the same number of bytes as that of an unsigned integer variable.

Operations with pointers

& – address / location operator (Address of ...)
* – dereferencing operator (Value at address ...)

```
int i, *ip; ip = &i;
*ip = 10; // same as i = 10

char c, *cp; cp = &c;
*cp = 'a'; // same as c = 'a'
```

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```
char c, *cp; cp = &c;
*cp = 'a'; // same as c = 'a'
```

`ip + n` – Points to the *n*-th object after what `ip` is pointing to
`ip - n` – Points to the *n*-th object before what `ip` is pointing to

Note: A pointer that has not yet been initialized (points to nothing) is known as a *wild* pointer.

`const char *` vs `char *const` vs `const char * const`

- `const char *ptr`: This is a pointer to a constant character. One cannot change the value pointed by ptr, but you can change the pointer itself.
- `char *const ptr`: This is a constant pointer to non-constant character. One cannot change the pointer p, but can change the value pointed by ptr.
- `const char *const ptr`: This is a constant pointer to constant character. One can neither change the value pointed by ptr nor the pointer ptr.

const char * vs char *const vs const char * const

Use of `const char *ptr`:

```
char x ='A', y ='B';
const char *ptr = &x;
printf("ptr is pointing to the value: %c\n", *ptr);
printf("ptr is pointing to the address: %u\n", ptr);
ptr = &y; // Writing *ptr = y is illegal
printf("ptr is pointing to the value: %c\n", *ptr);
printf("ptr is pointing to the address: %u\n", ptr);
```

const char * vs char *const vs const char * const

Use of `const char *ptr`:

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const char *ptr = &x;
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ptr = &y; // Writing *ptr = y is illegal
printf("ptr is pointing to the value: %c\n", *ptr);
printf("ptr is pointing to the address: %u\n", ptr);
```

Output:

ptr is pointing to the value: A
ptr is pointing to the address: 221652998
ptr is pointing to the value: B
ptr is pointing to the address: 221652999

const char * vs char *const vs const char * const

Use of `char *const ptr`:

```
char x ='A', y ='B';
char *const ptr = &x;
printf("ptr is pointing to the value: %c\n", *ptr);
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*ptr = y; // Writing ptr = &y is illegal
printf("ptr is pointing to the value: %c\n", *ptr);
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Output:

ptr is pointing to the value: A
ptr is pointing to the address: 221652998
ptr is pointing to the value: B
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Use of `const char *const ptr`:

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printf("ptr is pointing to the value: %c\n", *ptr);
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// Writing ptr = &y and *ptr = y are both illegal
```

Output:

ptr is pointing to the value: A

ptr is pointing to the address: 221652998

Void pointers

A void pointer, irrespective of the data type, points to some arbitrary data location in storage.

```
int i = 10;
char c = ‘a’;
void *p;
p = &i; // Points to an integer variable
printf("Integer value: %d", *((int*)p));
p = &c; // Points to a character variable
printf("\nCharacter value: %c", *((char*)p));
```

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char c = ‘a’;
void *p;
p = &i; // Points to an integer variable
printf("Integer value: %d", *((int*)p));
p = &c; // Points to a character variable
printf("\nCharacter value: %c", *((char*)p));
```

Note: A void pointer variable cannot be dereferenced in general. However, it can be done via typecasting.

Pointers and arrays

An array name is synonymous with the address of its first element.

Conversely, a pointer can be regarded as an array of elements starting from wherever it is pointing.

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```
int a[10] = {...}, *p;

p = a;          // same as p = &(a[0]);
*p = 5;         // same as a[0] = 5;
p[2] = 6;       // same as a[2] = 6;
*(a+3) = 7;     // same as a[3] = 7;
```

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*(a+3) = 7;     // same as a[3] = 7;
```

Note:

`p = a; p++;` RIGHT `a = p; a++;` WRONG

The concept of base address

The following representations are basically the same

```
a[i]
i[a]
*(a+i)
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i[a]
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So, the base address becomes &a[0] = &(*(a+0)) = &(*a) = *(&a) = a and the value at base address is a[0] = *(a+0) = *a.

Allocating, deallocating and reallocating memory

Syntax:

```
(type *)malloc(n*sizeof(type))  // Default garbage value
(type *)calloc(n, sizeof(type)) // Default zero value
(type *)realloc(ptr, n*sizeof(type))

free(ptr)
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Convenient macros:

```
#define Malloc(n,type) (type *)malloc((unsigned) ((n)*sizeof(type)))
#define Realloc(loc,n,type) (type *)realloc( (char *)(loc), \
                            (unsigned) ((n)*sizeof(type)))
```

Dangling pointers

A pointer turns out to be *dangling* if the block of memory it points to is made free.

```
int *a, cols;
a = (int *)malloc(cols*sizeof(int));
...
free(a); // Turns ‘a’ into a dangling pointer
a = NULL; // Restricts ‘a’ from being dangling
```

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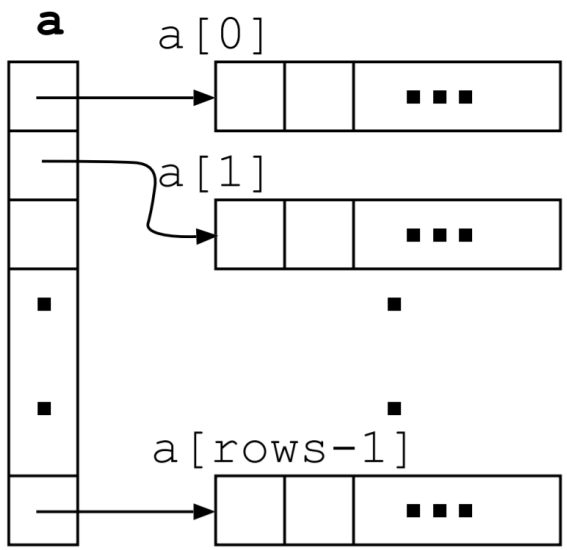
```

Note: A pointer is converted to a NULL Pointer, which points to nothing, so that it no more remains dangling.

Multi-dimensional arrays

Multi-dimensional array = array of arrays = pointer to pointer

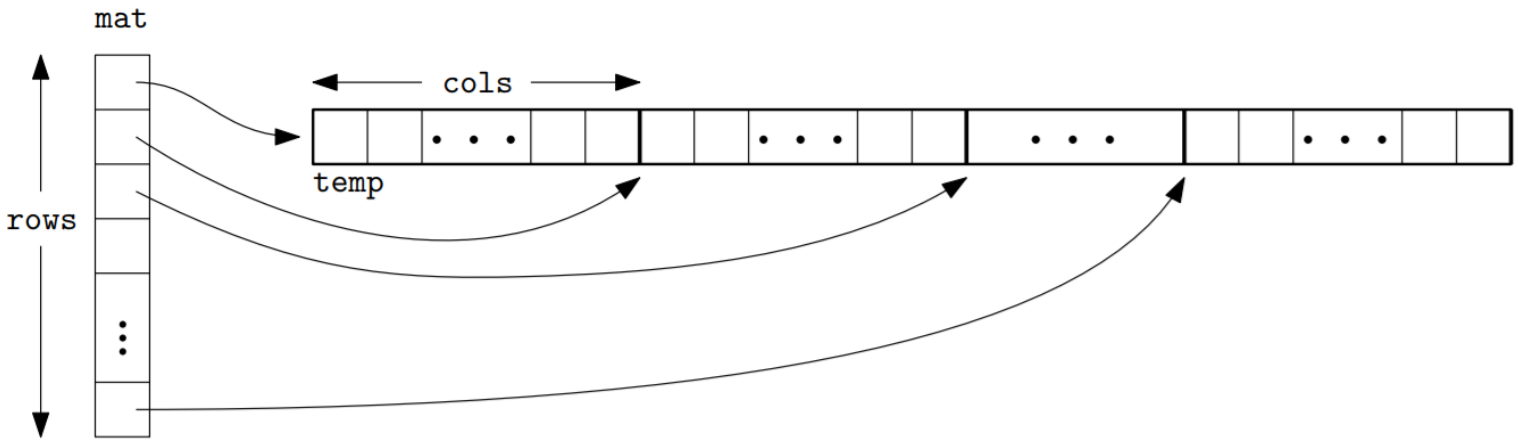
```
int **a, i;
a = (int **)malloc(rows*sizeof(int *));
for(i=0;i<rows;i++)
    a[i] = (int *)malloc(cols*sizeof(int));
```



Multi-dimensional arrays

```
for(i=0;i<rows;i++){
    free(a[i]);
}
free(a);
```

Multi-dimensional arrays




```
int ii;
int *temp;
if(NULL == (temp=(int *)malloc(rows*cols*sizeof(int))) ||
    NULL == (mat=(int **)malloc(rows * sizeof(int *))))
    ERR_MESG("Out of memory");
for(ii=0;ii<rows;temp += cols,ii++)
    mat[ii] = temp;
```

Review questions

1. Suppose `s` and `t` are strings. What does the following do?

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

2. What output is generated by the following code?

```
for(i=0;i<=10;i++)
    printf("abcdefghijklmnop\n" + i);
```

Review questions — Solutions

1. String copying

```
do{
    *s = *t;
    s++; t++;
}while(*t != '\0');
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    *s = *t;
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```
do{
    *s++ = *t++;
}while(*t != '\0');
```

```
while((*s++ = *t++) != '\0');
```

Review questions — Solutions

2. Think of the problem this way:

```
p = "abcdefghijklmnop\n";
printf(p);
```

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```
p = "abcdefghijklmnop\n";
printf(p + 2);
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Review questions — Solutions

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printf(p);
```

```
p = "abcdefghijklmnop\n";
printf(p + 2);
```

```
p = "abcdefghijklmnop\n";
printf(p + i);
```