

# Pointers

# Review

- recursion
  - scoping rule enforced by auto class
  - solution formation
- arrays and pointers

```
double  a[2], *p, *q;
```

```
p = a;           /* points to base of array */  
q = p + 1;       /* equivalent to q = &a[1] */  
printf("%d\n", q - p);           /* 1 is printed */  
printf("%d\n", (int) q - (int) p); /* 8 is printed */
```

- call-by-reference

# Relation between Arrays and Pointers

- `int a[10], i;`
  - `a[i]` is equivalent to `*(a + i)`
  
- `int i, *p`
  - `p[i]` is equivalent to `*(p + i)`
  
  - `a + i` is equivalent to `&a[i]`

# Arrays as Function Arguments

- When an array is passed as an argument to a function, the base address *value* is passed.
  - the array elements are not copied
- equivalent function headers

```
double sum(double a[], int n);  
double sum(double *a, int n)
```

```
double sum(double a[], int n)
    /* n is the size of a[] */
{
    int    i;
    double sum = 0.0;

    for (i = 0; i < n; ++i)
        sum += a[i];
    return sum;
}
```

```
int a[] = {7, 3, 66, 3, -5, 22, 77, 2};  
        bubble(a, 8);
```

```
void bubble(int a[], int n)  
            /* n is the size of a[] */  
{  
    int    i, j;  
    void    swap(int *, int *);  
  
    for (i = 0; i < n - 1; ++i)  
        for (j = n - 1; j > i; --j)  
            if (a[j-1] > a[j])  
                swap(&a[j-1], &a[j]);  
}
```

*Example: Bubble Sort (very inefficient, for array of size n, the number of comparisons is proportional to  $n^2$ )*

[bubblesort.c](#)

# Dynamic Memory Allocation

- The standard C lib contains
  - `void * calloc(int n, int m)`
  - `void * malloc(int m);`
    - if failed, NULL is returned
- `calloc (n, m)` is equivalent to
  - `p = malloc (n*m)`
  - `memset(p, 0, m*n);`

```
#include <stdio.h>
#include <stdlib.h>

int main(void)
{
    int *a;          /* to be used as an array */
    int n;          /* the size of the array */
    scanf("%d", &n);
    a = calloc(n, sizeof(int)); /* get space for a */
    ...             /* use a as an array */
    free(a); /* release space occupied by an array a */
}
```



# Memory Release

- You'd better free the allocated space
  - `free(p);`
  - `p` must be the pointer to the space allocated by `calloc()` or `malloc()`
- If you forget to free,
  - it will be freed when the process exits for some systems like Linux, Windows
  - for some other systems, nothing is guaranteed

# Strings

- review
  - `char *p = "abcde";`
  - `char s[] = "abcde";`
  - `char s[] = {'a', 'b', 'c', 'd', 'e', '\0'};`

```
#include <ctype.h>
```

```
int word_cnt(char *s)
```

```
{
```

```
    int    cnt = 0;
```

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

```
        while (isspace(*s))        /* skip white space */
```

```
            ++s;
```

```
        if (*s != '\0') {          /* found a word */
```

```
            ++cnt;
```

```
            while (!isspace(*s) && *s != '\0')
```

```
                ++s;              /* skip the word */
```

```
        }
```

```
    }
```

```
    return cnt;
```

```
}
```

# String Functions

- ANSI C Lib contains many useful functions
  - `char *strcat(char *s1, const char *s2);`
    - result is in `*s1`
    - what if there is no space after `s1`?
  - `int strcmp(const char *s1, const char *s2);`
    - returns negative, zero, positive depending on the lexicographical order
  - `char *strcpy(char *s1, const char *s2);`
    - copy `s2` to `s1`
    - what if `s2` is longer than `s1`?
  - `size_t strlen(const char *s);`
    - `size_t` is usually unsigned int

```
unsigned strlen(const char *s)
{
    register int    n;

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

```
char    *strcat(char *s1, const char *s2)
{
    register char    *p = s1;

    while (*p)
        ++p;
    while (*p++ = *s2++)
        ;
    return s1;
}
```

Declarations and initializations

```
char    s1[] = "beautiful big sky country",  
        s2[] = "how now brown cow";
```

ExpressionValue

```
strlen(s1)
```

25

```
strlen(s2+8)
```

9

```
strcmp(s1, s2)
```

negative integer

StatementsWhat gets printed

```
printf("%s", s1 + 10)
```

big sky country

```
strcpy(s1 + 10, s2 + 8)
```

```
strcat(s1, "s!")
```

```
printf("%s", s1)
```

beautiful brown cows!

# Multidimensional Arrays

- An array of arrays can be created
  - `double a[3][7];`
  - it is an array of three `a[7]`'s
  - the base address is `&a[0][0]`, NOT `a`
- You can expand it to three dimensional arrays



`int a[3][5]`

	Col 1	Col 2	Col 3	Col 4	Col 5
Row 1	<code>a[0][0]</code>	<code>a[0][1]</code>	<code>a[0][2]</code>	<code>a[0][3]</code>	<code>a[0][4]</code>
Row 2	<code>a[1][0]</code>	<code>a[1][1]</code>	<code>a[1][2]</code>	<code>a[1][3]</code>	<code>a[1][4]</code>
Row 3	<code>a[2][0]</code>	<code>a[2][1]</code>	<code>a[2][2]</code>	<code>a[2][3]</code>	<code>a[2][4]</code>

Expression equivalent to `a[i][j]`

`*(a[i] + j)`  
`(* (a + i)) [j]`  
`* ((* (a + i)) + j)`  
`* (&a[0][0] + 5*i + j)`

# Initialization

Three equivalent initializations:

```
int  a[2][3] = {1, 2, 3, 4, 5, 6};  
int  a[2][3] = {{1, 2, 3}, {4, 5, 6}};  
int  a[][3] = {{1, 2, 3}, {4, 5, 6}};  
  
int  a[2][2][3] = {0};  
/* all elements of a initialized to 0 */
```

# Arrays of Pointers

- `char *w[N];`
  - an array of pointers
  - each pointer is to char
- ragged array
  - `char *p[2] = {"abc", "1234567890"};`

read the `sort_words` example in the textbook

# Arguments to main( )

- argc and argv are used for main()
  - argc is the number of arguments
  - argv is an array of pointers
    - argv[0] is the name of the main program
    - then naturally,  $\text{argc} \geq 1$

```
#include <stdio.h>
```

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

my\_echo.c

```
{  
    int    i;  
  
    printf("argc = %d\n", argc);  
    for (i = 0; i < argc; ++i)  
        printf("argv[%d] = %s\n", i, argv[i]);  
    return 0;  
}
```

```
$ my_echo midterm is on Thursday
```



# Functions as Arguments

- a function name can be passed as an argument
- think a function name as a pointer (like an array)
- $(*f)(x)$ 
  - $f$  is a pointer to a function
  - $*f$  is a function
  - $(*f)(x)$  is call to the function
- if you are still confused, just follow the example

```
#include <math.h>
#include <stdio.h>

double    f(double) ;
double    sum_square(double (*)(double), int, int);
```

```
#include "sum_sqr.h"

int main(void)
{
    printf("%s%.7f\n%s%.7f\n",
        " First computation: ", sum_square(f, 1, 10000),
        "Second computation: ", sum_square(sin, 2, 13));
    return 0;
}
```



```
double sum_square(double f(double), int m, int n)
{
    int    k;
    double sum = 0.0;

    for (k = m; k <= n; ++k)
        sum += f(k) * f(k);
    return sum;
}
```

```
double f(double x)
{
    return 1.0 / x;
}
```

# Functions as Arguments

- double g(double) returns double
- double \*g(double) returns a pointer
  
- equivalent function prototype definitions

```
double sum_square(double f(double x), int m, int n);  
double sum_square(double f(double), int m, int n);  
double sum_square(double f(double), int, int);  
double sum_square(double (*f)(double), int, int);  
double sum_square(double (*)(double), int, int);
```

# const volatile

- `const int N = 3;`
  - `i` cannot be changed after initialization
  - `i` cannot be used for array definition like
    - `int k[N];`
- `extern const volatile int real_time_clock;`
  - this variable is modified by other part of a computer,
  - but you cannot change the value, JUST READ it