Language C: Scopes and Memory management

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Scope and Extent. . .

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The extent of a variable or function refers to its lifetime in terms of when memory is allocated to store it, and when that memory is released.

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void afunction(int a, int b)
{
    double val;
    ...
    {
        int val2 = 5;
        ...
    } /* val2 goes out-of-scope here */
    ...
} /* a, b, val go out-of-scope here */
```

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```

A local variable has automatic extent: its lifetime is from the point it is defined until the end of its block.

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At the end of the block, the variable is destroyed and the memory recovered; the variable is said to go out-of-scope.

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The `extern` keyword is used to declare the existence of an external variable in one file when it is defined in another.

External Scope and Static Extent: Example

File one.c:

```
int globalvar;  /* external variable definition */
extern double myvariable; /* external variable
                  declaration (defined elsewhere) */
void myfunc(int idx); /* external function
                        prototype (declaration) */
```

File two:

```
double myvariable = 3.2; /* external variable
                                   definition */
void myfunc(int idx)
/* Function definition */
{
    extern int globalvar; /* external variable
                                 declaration */
    ...
}
```

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The value of an external variable is retained from one function call to the next.

Static Extent: Remarks

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They may also permit more natural semantics if two functions operate on the same data, but neither calls the other.

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However:

- this may lead to strong dependencies between functions
  - . . . this violates the modular design principles of decoupled functions accessible only well-defined interfaces;
- it is easy to write code where the same identifier is used to define two different external variables;
- nasty and unexpected *side-effects* may be experienced.

Storage Class Specifier: `static`

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```
int increment(void)
  {
       static int local_static;
       return local_static++;
  }
```

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File one.c:

```
static double myvariable;
static void myfunc(int idx);
```

File two.c:

```
static int myvariable;      /* no conflict */
static int myfunc(int idx); /* no conflict */
```

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Inclusion of header files is performed by the C preprocessor as specified by the #include directive.

The standard library headers are included using angle brackets to enclose the filename:

```
#include <filename.h>
```

Double quotes are used to indicate that the included file is local available:

```
#include "filename.h"
```

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- object modules are linked to form the complete program.

Separate compilation, in conjunction with the *C* scoping rules, gives rise to the paradigm of modular programming.

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Private interface declarations are not added to the header file, but are declared at the top of the source file.

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- Modules are decoupled from the rest of the program, allowing them to be built, tested, and debugged in isolation.
- Modules facilitate team program development where individuals can each work on different modules that make up the program.

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A pointer is a variable whose value is the address of another variable.

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Let us consider the following portion of code:

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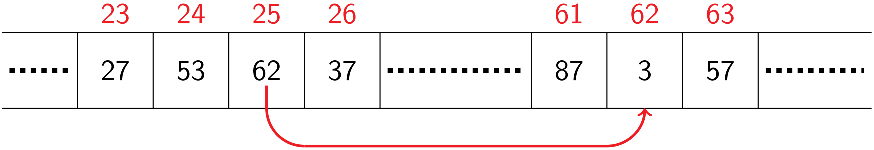
Notice that a pointer is just another type of variable; it, also, has an address and may in turn be pointed-to by a pointer-to-a-pointer variable.

Pointers: An Example

Variable	Type	Address	Value
x	char	62	3
px	char∗	25	62



	23	24	25	26		61	62	63	
......	27	53	62	37	....	87	3	57	....

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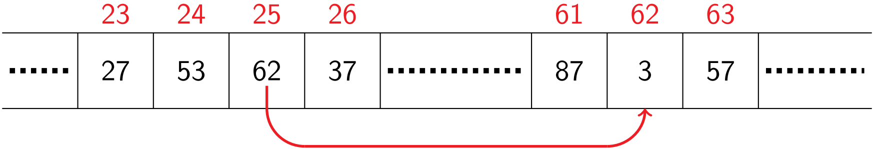

The pointer datatype (char*) is crucial to retrieve values from memory location!

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C compiler uses the associated pointer type to behave appropriately with sequences of a particular type (e.g., an array of doubles).

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A pointer of a particular type is declared using the * symbol, and the address of a variable is obtained using the address-of operator &:

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It is worth noting that the $*$ in a list of definitions refers only to the adjacent variable, and the spacing is irrelevant:

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int* i, j, * k;
```

Standard: `int* i, j, * k;`

Pointer Syntax. . .

The value of the variable to which a pointer points can be obtained using the indirection or dereferencing operator ∗:

```
int i = 2;

int *j = &i; /* Define a pointer-to-int j,
                and initialise with address of i. */

int x = *j;  /* x is assigned the value pointed by
                value of j (that is value of i)
                (that is, 2). */
```

The dereferencing use of ∗ should not be confused with its use in pointer-declaration syntax!

- in declaration it means is a pointer-type variable;
- in all other circumstances means access the pointed-to object.

Pointer Syntax: Examples

```
char c = 'A';
char *pc = &c; /* pc points to c */
double d = 5.34;
double *pd1, *pd2;
*pc = 'B'; /* Dereferenced pointer:
              c is now equal to 'B'. */
pd1=&d;    /* pd1 points to d */
pd2 = pd1; /* pd2 and pd1 now both point to d. */
*pd1 = *pd2 * 2.0; /* Equivalent to d = d * 2.0; */
```

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The exception to this rule is the `void*` pointer, which may be assigned to a pointer of any type without a cast.

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#define NULL    ((void*) 0)
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The constant values 0 or 0L may be used in place of NULL to specify a null-pointer value, but the symbolic constant is usually the more readable option.

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The first, and most common, is to declare the pointer const so that the object to which it points cannot be changed.

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int i = 5, j = 6;
const int *p = &i;
*p = j; /* Invalid. Cannot change i via p. */
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However, the pointer itself may be changed to point to another object:

```
int i = 5, j = 6;
const int *p = &i;
p = &j; /* Valid. p now points to j. */
*p = i; /* Invalid. Cannot change j via p. */
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That is, the pointer value may not change, but the value of the object to which it points may change:

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int i = 5, j = 6;
int * const p = &i;
*p = j; /* Valid. i is now 6 */
p = &j; /* Invalid. p must always point to i. */
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```

It is possible to combine these two forms to define a non-changing pointer to a non-changeable data:

```
int i = 5, j = 6;
const int * const p = &i;
*p = j; /* Invalid. i cannot be changed via p. */
p = &j; /* Invalid. p must always point to i. */
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```
swap(a, b); /* Pass values of a and b, respectively. */

void swap(int x, int y)
/* x and y are copies of the passed arguments. */
{
    int tmp = x; /* x is unrelated to a */
    x = y;       /* this operation does not affect a. */
    y = tmp;
 }
```

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Pointers, as with any other variable, are passed by value, but their values are addresses which still point to the original variables:

```
swap(&a, &b); /* Pass pointers to a and b */
void swap(int* px, int* py)
/* px and py are copies of the passed arguments. */
{
    int tmp = *px; /* The value of px is still the
                      address of a */
    *px = *py;     /* so this dereferencing operation
                      is equivalent to a = b. */
    *py = tmp;
}
```

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Whenever an array name appears in an expression, it is automatically converted to a pointer to its first element:

```
unsigned buffer[256];
unsigned *pbuff1 = buffer; /* Buffer converted to
                             pointer, & not required. */

unsigned *pbuff2 = buffer + 5;
                             /* A "pointer-plus-offset"
                                expression. */
```

Pointers and arrays...

An array name and a pointer to an array may be used interchangeably in many circumstances, such as array indexing:

```
char letters[26];
char *pc1 = letters; /* Equivalent pointer values. */
char *pc2 = &letters;
char *pc3 = &letters[0];

letters[4] = 'e'; /* Equivalent indexes. */
pc1[4] = 'e';
*(letters + 4) = 'e';
*(pc2 + 4) = 'e';

pc3 = &letters[10]; /* Equivalent addresses. */
pc3 = &pc1[10];
pc3 = letters + 10;
pc3 = pc2 + 10;
```

Pointers and arrays...

Differences

An array is not a variable; its value cannot be changed.

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int a1[10], a2[10];
int *pa = a1;
a1 = a2; /* Error: won't compile. */
a1++;    /* Error: won't compile. */
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The size of an array is the number of characters of memory allocated, while the size of a pointer is just the size of the pointer variable.

```
double a1[10];
double *pa = a1;
size_t s1 = sizeof(a1);/* s1 equals 10*sizeof(double) */
size_t s2 = sizeof(pa);/* s2 equals sizeof(double *) */
```

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```
float fval, array[10];
float *p1, *p2, *p3 = &array[5];
int i=2, j;
p1 = NULL; /* Assignment to NULL (or to 0 or 0L). */
p2 = &fval; /* Assignment to an address. */
p1 = p2; /* Assignment to another pointer (of same type). */
p2 = p3 - 4; /* Addition or subtraction by an integer: a
    pointer-offset expression. */
p2+=i; /* Another pointer-offset expression. */
j = p3 - p2; /* Pointer subtraction: gives the number of
    elements between p2 and p3. */
i = p2 < p3; /* Relational operations <, >, ==, !=, <=, >= */
```

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```
int* misguided(void)
{
    int array[10], i; /* array has local extent:
destroyed at end-of-block. */
    for (i = 0; i < 10; ++i)
        array[i] = i;
    return array;
}
```

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double* geometric_growth(void)
{
    static double grows = 0.1;
    grows *= 1.1;
    return &grows;
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Example 2: A reference to an element within a passed array

```
char* find_first(char* str, char c)
{
    while(*str++ != '\0')
        if (*str == c) return str;
    return NULL;
}
```

Function Pointers

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```
double (*pf)(double, int);
```

The parenthesis around ∗pf are crucial to specify that pf is a function pointer and not a function returning pointer!

Function Pointers: Example (Part1)

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

double add(double a, double b) {
  return a + b;
}

double sub(double a, double b) {
  return a - b;
}

double mult(double a, double b) {
  return a * b;
}

double div(double a, double b) {
  assert(b != 0.0); return a / b;
}
```

Function Pointers: Example (Part2)

```
void execute operation(double (*f)(double,double), double x,
    double y)
{
  double result = f(x,y);
  printf(”Result of operation on %3.2f and %3.2f is %7.4f\n”,
     x, y, result);
}

int main(void)
{
  double val1=4.3, val2=5.7;
  execute operation(add, val1, val2);
  execute operation(sub, val1, val2);
  execute operation(mult, val1, val2);
  execute operation(div, val1, val2);
}
```