CMSC 313
COMPUTER ORGANIZATION
&
ASSEMBLY LANGUAGE
PROGRAMMING

LECTURE 17, FALL 2012

TOPICS TODAY

- **Project 7**
- **Function pointers**

FUNCTION POINTERS

DECLARING FUNCTION POINTERS

- Declaring a pointer to `int` value:

```
int *iptr ;
```

- Declaring a pointer to a function that takes an `int` parameter and returns an `int` value:

```
int (*fptr1) (int) ;
```

- Declaring a pointer to a function that takes two `int` parameters and returns an `int` value:

```
int (*fptr2) (int, int) ;
```

ASSIGNING VALUES TO FUNCTION POINTERS

- Assigning a value to an `int` pointer:

```
int a ;
int *iptr = &a ;
```

- Assigning a value to a function pointer:

```
int add3(int) ;
int sum (int, int) ;
int (*fptr1) (int) ;
int (*fptr2) (int, int) ;

fptr1 = &add3 ;
fptr2 = &sum ;
```

INVOKING FUNCTION POINTERS

```
int add3(int) ;
int sum (int, int) ;
int b ;

fptr1 = &add3 ;
b = (*fptr1) (5) ;

fptr2 = &sum ;
b = (*fptr2) (6, b) ;
```

```c
/* File: funcptr1.c

   Demonstrating function pointers.

*/

#include <stdio.h>

int add3 (int n) {
   return n + 3 ;
}

int add5 (int n) {
   return n + 5 ;
}


int main() {

   int a, b  ;
   int (* fptr) (int) ;

   a = 7 ;
   printf("a = %d\n", a) ;

   fptr = &add3 ;
   b = (*fptr) (a) ;
   printf("fptr(a) = %d\n", b ) ;

   fptr = &add5 ;
   b = (*fptr) (a) ;
   printf("fptr(a) = %d\n", b ) ;

   return 0 ;
}
```

```
Script started on Wed Oct 17 23:08:55 2012
River[1]% gcc -Wall funcptr1.c

River[2]% ./a.out
a = 7
fptr(a) = 10
fptr(a) = 12
River[3]%

River[3]% exit
exit

Script done on Wed Oct 17 23:09:11 2012
```

```c
/* File: funcptr2.c

   Demonstrating function pointers.

*/

#include <stdio.h>

int add3 (int n) {
   return n + 3 ;
}

int add5 (int n) {
   return n + 5 ;
}

typedef int (* INT_INT_FPTR) (int) ;

void do_array(int A[], int size, INT_INT_FPTR fptr) {
   int i ;

   for ( i = 0 ; i < size ; i++) {
      A[i] = (* fptr) (A[i]) ;
   }
}


int main() {

   int A[10], i  ;

   for (i = 0 ; i < 10 ; i++) {
      A[i] = i * i ;
   }

   printf("Original array A[]:\n") ;
   for (i = 0 ; i < 10 ; i++) {
      printf("A[%d] = %d\n", i, A[i])  ;
   }

   do_array(A, 10, &add3) ;

   printf("\n\n After calling do_array(A, 10, &add3):\n") ;
   for (i = 0 ; i < 10 ; i++) {
      printf("A[%d] = %d\n", i, A[i]) ;
   }

   do_array(A, 10, &add5) ;

   printf("\n\n After calling do_array(A, 10, &add5):\n") ;
   for (i = 0 ; i < 10 ; i++) {
      printf("A[%d] = %d\n", i, A[i]) ;
   }

   return 0 ;
}
```

```
Script started on Wed Oct 17 23:09:20 2012
River[4]% gcc -Wall funcptr2.c

River[5]% ./a.out
Original array A[]:
A[0] = 0
A[1] = 1
A[2] = 4
A[3] = 9
A[4] = 16
A[5] = 25
A[6] = 36
A[7] = 49
A[8] = 64
A[9] = 81


 After calling do_array(A, 10, &add3):
A[0] = 3
A[1] = 4
A[2] = 7
A[3] = 12
A[4] = 19
A[5] = 28
A[6] = 39
A[7] = 52
A[8] = 67
A[9] = 84


 After calling do_array(A, 10, &add5):
A[0] = 8
A[1] = 9
A[2] = 12
A[3] = 17
A[4] = 24
A[5] = 33
A[6] = 44
A[7] = 57
A[8] = 72
A[9] = 89
River[6]%
River[6]% exit
exit

Script done on Wed Oct 17 23:09:33 2012
```

```c
/* File: funcptr3.c

   Demonstrating function pointers.

*/


#include <stdio.h>


int diff (int m, int n) {
   return m - n ;
}

int sum (int m, int n) {
   return m + n ;
}

typedef int (* FPTR2) (int, int) ;

void do_array(int A[], int B[], int size, FPTR2 fptr) {
   int i ;

   for ( i = 0 ; i < size ; i++) {
      A[i] = (* fptr) (A[i], B[i]) ;
   }
}


int main() {

   int A[10], B[10], i  ;

   for (i = 0 ; i < 10 ; i++) {
      A[i] = i * i ;
      B[i] = 2 * i ;
   }

   printf("Original arrays:\n") ;
   for (i = 0 ; i < 10 ; i++) {
      printf("A[%d] = %d,   B[%d] = %d\n", i, A[i], i, B[i])  ;
   }

   do_array(A, B, 10, &diff) ;

   printf("\n\n After calling do_array(A, B, 10, &diff):\n") ;
   for (i = 0 ; i < 10 ; i++) {
      printf("A[%d] = %d,   B[%d] = %d\n", i, A[i], i, B[i])  ;
   }

   do_array(A, B, 10, &sum) ;

   printf("\n\n After calling do_array(A, 10, &sum):\n") ;
   for (i = 0 ; i < 10 ; i++) {
      printf("A[%d] = %d,   B[%d] = %d\n", i, A[i], i, B[i])  ;
   }

   return 0 ;
}
```

```
Script started on Wed Oct 17 23:09:41 2012
River[7]% gcc -Wall funcptr3.c
River[8]%

River[8]% ./a.out
Original arrays:
A[0] = 0,   B[0] = 0
A[1] = 1,   B[1] = 2
A[2] = 4,   B[2] = 4
A[3] = 9,   B[3] = 6
A[4] = 16,   B[4] = 8
A[5] = 25,   B[5] = 10
A[6] = 36,   B[6] = 12
A[7] = 49,   B[7] = 14
A[8] = 64,   B[8] = 16
A[9] = 81,   B[9] = 18


 After calling do_array(A, B, 10, &diff):
A[0] = 0,   B[0] = 0
A[1] = -1,   B[1] = 2
A[2] = 0,   B[2] = 4
A[3] = 3,   B[3] = 6
A[4] = 8,   B[4] = 8
A[5] = 15,   B[5] = 10
A[6] = 24,   B[6] = 12
A[7] = 35,   B[7] = 14
A[8] = 48,   B[8] = 16
A[9] = 63,   B[9] = 18


 After calling do_array(A, 10, &sum):
A[0] = 0,   B[0] = 0
A[1] = 1,   B[1] = 2
A[2] = 4,   B[2] = 4
A[3] = 9,   B[3] = 6
A[4] = 16,   B[4] = 8
A[5] = 25,   B[5] = 10
A[6] = 36,   B[6] = 12
A[7] = 49,   B[7] = 14
A[8] = 64,   B[8] = 16
A[9] = 81,   B[9] = 18
River[9]%

River[9]% exit
exit

Script done on Wed Oct 17 23:09:55 2012
```

NAME

qsort – sorts an array

SYNOPSIS

#include <stdlib.h>

void qsort(void ****base*, size_t** *nmemb***, size_t** *size***,**
int(**compar***)(const void *, const void *));**

DESCRIPTION

The **qsort**() function sorts an array with *nmemb* elements of size *size*. The *base* argument points to the start of the array.

The contents of the array are sorted in ascending order according to a comparison function pointed to by *compar*, which is called with two arguments that point to the objects being compared.

The comparison function must return an integer less than, equal to, or greater than zero if the first argument is considered to be respectively less than, equal to, or greater than the second. If two members compare as equal, their order in the sorted array is undefined.

RETURN VALUE

The **qsort**() function returns no value.

CONFORMING TO

SVr4, 4.3BSD, C89, C99.

NOTES

Library routines suitable for use as the *compar* argument include **alphasort**(3) and **versionsort**(3). To compare C strings, the comparison function can call **strcmp**(3), as shown in the example below.

EXAMPLE

For one example of use, see the example under **bsearch**(3).

Another example is the following program, which sorts the strings given in its command-line arguments:

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

static int
cmpstringp(const void *p1, const void *p2)
{
   /* The actual arguments to this function are "pointers to
      pointers to char", but strcmp(3) arguments are "pointers
      to char", hence the following cast plus dereference */

   return strcmp(* (char * const *) p1, * (char * const *) p2);
}

int
main(int argc, char *argv[])
{
   int j;

   assert(argc > 1);

   qsort(&argv[1], argc - 1, sizeof(char *), cmpstringp);
```

```
    for (j = 1; j < argc; j++)
        puts(argv[j]);
    exit(EXIT_SUCCESS);
}
```

SEE ALSO

sort(1), **alphasort**(3), **strcmp**(3), **versionsort**(3)

COLOPHON

This page is part of release 3.22 of the Linux *man-pages* project. A description of the project, and information about reporting bugs, can be found at http://www.kernel.org/doc/man-pages/.

```c
/* File: qsort1.c

   Demonstrating use of callback functions in qsort().
*/

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


typedef int (* COMP_FUNC_PTR) (const void *, const void *) ;

int lessthan (int *ptr1, int *ptr2) {
   return *ptr1 - *ptr2 ;
}

int main() {
  int A[25] = {  2,  7, 91, 23, 14, 72, 19, 31, 44, 62,
                34, 11, 51, 62, 22, 81, 45, 54, 67, 74,
                24, 15, 41, 83, 88} ;
   int i ;

   printf("Original array:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      printf("  A[%d] = %d\n", i, A[i]) ;
   }

   qsort(A, 25, sizeof(int), (COMP_FUNC_PTR) &lessthan) ;

   printf("\n\nSorted array:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      printf("  A[%d] = %d\n", i, A[i]) ;
   }

   return 0 ;
}
```

```
Script started on Wed Oct 17 23:14:12 2012
River[10]% gcc qsort1.c
River[11]%
River[11]% ./a.out
Original array:
  A[0] = 2
  A[1] = 7
  A[2] = 91
  A[3] = 23
  A[4] = 14
  A[5] = 72
  A[6] = 19
  A[7] = 31
  A[8] = 44
  A[9] = 62
  A[10] = 34
  A[11] = 11
  A[12] = 51
  A[13] = 62
  A[14] = 22
  A[15] = 81
  A[16] = 45
  A[17] = 54
  A[18] = 67
  A[19] = 74
  A[20] = 24
  A[21] = 15
  A[22] = 41
  A[23] = 83
  A[24] = 88


Sorted array:
  A[0] = 2
  A[1] = 7
  A[2] = 11
  A[3] = 14
  A[4] = 15
  A[5] = 19
  A[6] = 22
  A[7] = 23
  A[8] = 24
  A[9] = 31
  A[10] = 34
  A[11] = 41
  A[12] = 44
  A[13] = 45
  A[14] = 51
  A[15] = 54
  A[16] = 62
  A[17] = 62
  A[18] = 67
  A[19] = 72
  A[20] = 74
  A[21] = 81
  A[22] = 83
  A[23] = 88
  A[24] = 91
River[12]%
```

```c
/* File: qsort2.c

   Demonstrating use of callback functions in qsort().
   This time use bigger data sizes.
*/

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


typedef int (* COMP_FUNC_PTR) (const void *, const void *) ;

typedef struct {
    char   realname[32] ;
    char   nickname[16] ;
    char   alignment[20] ;
    char   role[20] ;
    int    points ;
    int    level ;

} Player ;


Player records[25] = {
   {"Allen, Kevin P.", "kallen1", "neutral good", "Paladin", 6721, 6},
   {"Baker, Matthew R.", "mbaker5", "true neutral", "Thief", 4313, 4},
   {"Chandlee, Richard C.", "rchand1", "lawful evil", "Ranger", 3196, 3},
   {"Cloud, Clinton E.", "ccloud2", "chaotic good", "Magician", 9583, 9},
   {"Cobb, Milton T.", "cobb", "lawful neutral", "Fighter", 9169, 9},
   {"Frankle, Alan E.", "frankle1", "chaotic good", "Fighter", 8924, 9},
   {"Fu, David E.", "dfu1", "chaotic good", "Ranger", 10011, 12},
   {"Helton, Robert L.", "helton1", "true neutral", "Paladin", 3034, 3},
   {"Joshua, Aimee", "ajoshu1", "chaotic evil", "Thief", 3733, 4},
   {"Macdonald, Matthew S.", "matmacd1", "chaotic good", "Fighter", 3797, 5},
   {"Mcelvaney, Erin L.", "emcelv1", "lawful neutral", "Cleric", 9896, 11},
   {"Mitchell, Susan M.", "smitchel", "neutral good", "Fighter", 9740, 10},
   {"Mittal, Sandeep K.", "smitta1", "chaotic good", "Cleric", 2706, 2},
   {"Moore, Brian A.", "bmoore1", "lawful evil", "Ranger", 4016, 4},
   {"Napier, Matthew A.", "mnapie1", "true neutral", "Magician", 4539, 5},
   {"Nguyen, Michael D.", "mnguyen1", "chaotic good", "Ranger", 9490, 9},
   {"Orticke, Alecia G.", "aortic1", "chaotic good", "Cleric", 2048, 4},
   {"Palewicz, David E.", "dpalew1", "chaotic good", "Thief", 765, 3},
   {"Raby, Adam M.", "araby1", "lawful neutral", "Magician", 8814, 9},
   {"Roberts, Eric J.", "erober3", "neutral good", "Fighter", 7765, 7},
   {"Rusinko, Nicholas D.", "nrusin1", "lawful good", "Thief", 5095, 5},
   {"Seo, Maximilian", "mseo1", "chaotic evil", "Ranger", 3205, 3},
   {"Shenvi, Shilpa P.", "shenvi1", "neutral good", "Thief", 9573, 10},
   {"Szrom, Michelle L.", "mszrom1", "chaotic good", "Cleric", 9660, 9},
   {"Tuveson, Eric A.", "etuves1", "chaotic evil", "Thief", 9245, 7}
} ;



void PrintPlayer(Player *p) {

   printf("%32s (%16s)  %20s  %20s(%3d)  %10d\n",
      p->realname, p->nickname, p->alignment, p->role, p->level,
      p->points) ;
}
```

```
int byPoints(Player *p1, Player *p2) {
   return p1->points - p2->points ;
}

int byNickname(Player *p1, Player *p2) {
   return strcmp(p1->nickname, p2->nickname) ;
}

int byAlignment(Player *p1, Player *p2) {
   return strcmp(p1->alignment, p2->alignment) ;
}

int main () {

   int i ;

   printf("Original list:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(&records[i]) ;
   }


   qsort(records, 25, sizeof(Player), (COMP_FUNC_PTR) &byPoints) ;

   printf("\n\nSorted by points:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(&records[i]) ;
   }


   qsort(records, 25, sizeof(Player), (COMP_FUNC_PTR) &byNickname) ;

   printf("\n\nSorted by nickname:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(&records[i]) ;
   }


   qsort(records, 25, sizeof(Player), (COMP_FUNC_PTR) &byAlignment) ;

   printf("\n\nSorted by alignment:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(&records[i]) ;
   }

   return 0 ;
}
```

```c
/* File: qsort2.c

   Demonstrating use of callback functions in qsort().
   This time use bigger data sizes.
*/

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


typedef int (* COMP_FUNC_PTR) (const void *, const void *) ;

typedef struct {
    char   realname[32] ;
    char   nickname[16] ;
    char   alignment[20] ;
    char   role[20] ;
    int    points ;
    int    level ;

} Player ;


Player records[25] = {
   {"Allen, Kevin P.", "kallen1", "neutral good", "Paladin", 6721, 6},
   {"Baker, Matthew R.", "mbaker5", "true neutral", "Thief", 4313, 4},
   {"Chandlee, Richard C.", "rchand1", "lawful evil", "Ranger", 3196, 3},
   {"Cloud, Clinton E.", "ccloud2", "chaotic good", "Magician", 9583, 9},
   {"Cobb, Milton T.", "cobb", "lawful neutral", "Fighter", 9169, 9},
   {"Frankle, Alan E.", "frankle1", "chaotic good", "Fighter", 8924, 9},
   {"Fu, David E.", "dfu1", "chaotic good", "Ranger", 10011, 12},
   {"Helton, Robert L.", "helton1", "true neutral", "Paladin", 3034, 3},
   {"Joshua, Aimee", "ajoshu1", "chaotic evil", "Thief", 3733, 4},
   {"Macdonald, Matthew S.", "matmacd1", "chaotic good", "Fighter", 3797, 5},
   {"Mcelvaney, Erin L.", "emcelv1", "lawful neutral", "Cleric", 9896, 11},
   {"Mitchell, Susan M.", "smitchel", "neutral good", "Fighter", 9740, 10},
   {"Mittal, Sandeep K.", "smitta1", "chaotic good", "Cleric", 2706, 2},
   {"Moore, Brian A.", "bmoore1", "lawful evil", "Ranger", 4016, 4},
   {"Napier, Matthew A.", "mnapie1", "true neutral", "Magician", 4539, 5},
   {"Nguyen, Michael D.", "mnguyen1", "chaotic good", "Ranger", 9490, 9},
   {"Orticke, Alecia G.", "aortic1", "chaotic good", "Cleric", 2048, 4},
   {"Palewicz, David E.", "dpalew1", "chaotic good", "Thief", 765, 3},
   {"Raby, Adam M.", "araby1", "lawful neutral", "Magician", 8814, 9},
   {"Roberts, Eric J.", "erober3", "neutral good", "Fighter", 7765, 7},
   {"Rusinko, Nicholas D.", "nrusin1", "lawful good", "Thief", 5095, 5},
   {"Seo, Maximilian", "mseo1", "chaotic evil", "Ranger", 3205, 3},
   {"Shenvi, Shilpa P.", "shenvi1", "neutral good", "Thief", 9573, 10},
   {"Szrom, Michelle L.", "mszrom1", "chaotic good", "Cleric", 9660, 9},
   {"Tuveson, Eric A.", "etuves1", "chaotic evil", "Thief", 9245, 7}
} ;



void PrintPlayer(Player *p) {

   printf("%32s (%16s)  %20s  %20s(%3d)  %10d\n",
      p->realname, p->nickname, p->alignment, p->role, p->level,
      p->points) ;
}
```

```
int byPoints(Player *p1, Player *p2) {
   return p1->points - p2->points ;
}

int byNickname(Player *p1, Player *p2) {
   return strcmp(p1->nickname, p2->nickname) ;
}

int byAlignment(Player *p1, Player *p2) {
   return strcmp(p1->alignment, p2->alignment) ;
}

int main () {

   int i ;

   printf("Original list:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(&records[i]) ;
   }


   qsort(records, 25, sizeof(Player), (COMP_FUNC_PTR) &byPoints) ;

   printf("\n\nSorted by points:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(&records[i]) ;
   }


   qsort(records, 25, sizeof(Player), (COMP_FUNC_PTR) &byNickname) ;

   printf("\n\nSorted by nickname:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(&records[i]) ;
   }


   qsort(records, 25, sizeof(Player), (COMP_FUNC_PTR) &byAlignment) ;

   printf("\n\nSorted by alignment:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(&records[i]) ;
   }

   return 0 ;
}
```

```
Script started on Wed Oct 17 23:14:26 2012
River[13]% gcc -Wall qsort2.c
River[14]%
River[14]% ./a.out
Original list:
                Allen, Kevin P. (         kallen1)         neutral good             Paladin(  6)        6721
              Baker, Matthew R. (         mbaker5)         true neutral               Thief(  4)        4313
           Chandlee, Richard C. (         rchand1)          lawful evil              Ranger(  3)        3196
              Cloud, Clinton E. (         ccloud2)        chaotic good            Magician(  9)        9583
                Cobb, Milton T. (            cobb)      lawful neutral             Fighter(  9)        9169
               Frankle, Alan E. (         frankle1)        chaotic good             Fighter(  9)        8924
                   Fu, David E. (             dfu1)        chaotic good              Ranger( 12)       10011
              Helton, Robert L. (         helton1)         true neutral             Paladin(  3)        3034
                  Joshua, Aimee (         ajoshu1)        chaotic evil               Thief(  4)        3733
          Macdonald, Matthew S. (        matmacd1)        chaotic good             Fighter(  5)        3797
             Mcelvaney, Erin L. (         emcelv1)      lawful neutral              Cleric( 11)        9896
             Mitchell, Susan M. (        smitchel)        neutral good             Fighter( 10)        9740
             Mittal, Sandeep K. (         smitta1)        chaotic good              Cleric(  2)        2706
                Moore, Brian A. (         bmoore1)          lawful evil              Ranger(  4)        4016
             Napier, Matthew A. (         mnapie1)         true neutral            Magician(  5)        4539
             Nguyen, Michael D. (        mnguyen1)        chaotic good              Ranger(  9)        9490
             Orticke, Alecia G. (         aortic1)        chaotic good              Cleric(  4)        2048
             Palewicz, David E. (         dpalew1)        chaotic good               Thief(  3)         765
                  Raby, Adam M. (          araby1)      lawful neutral            Magician(  9)        8814
               Roberts, Eric J. (         erober3)        neutral good             Fighter(  7)        7765
            Rusinko, Nicholas D. (         nrusin1)         lawful good               Thief(  5)        5095
                 Seo, Maximilian (           mseo1)        chaotic evil              Ranger(  3)        3205
               Shenvi, Shilpa P. (         shenvi1)        neutral good               Thief( 10)        9573
              Szrom, Michelle L. (         mszrom1)        chaotic good              Cleric(  9)        9660
                Tuveson, Eric A. (         etuves1)        chaotic evil               Thief(  7)        9245


Sorted by points:
             Palewicz, David E. (         dpalew1)        chaotic good               Thief(  3)         765
             Orticke, Alecia G. (         aortic1)        chaotic good              Cleric(  4)        2048
             Mittal, Sandeep K. (         smitta1)        chaotic good              Cleric(  2)        2706
              Helton, Robert L. (         helton1)         true neutral             Paladin(  3)        3034
           Chandlee, Richard C. (         rchand1)          lawful evil              Ranger(  3)        3196
                 Seo, Maximilian (           mseo1)        chaotic evil              Ranger(  3)        3205
                   Joshua, Aimee (         ajoshu1)        chaotic evil               Thief(  4)        3733
          Macdonald, Matthew S. (        matmacd1)        chaotic good             Fighter(  5)        3797
                Moore, Brian A. (         bmoore1)          lawful evil              Ranger(  4)        4016
              Baker, Matthew R. (         mbaker5)         true neutral               Thief(  4)        4313
             Napier, Matthew A. (         mnapie1)         true neutral            Magician(  5)        4539
           Rusinko, Nicholas D. (         nrusin1)         lawful good               Thief(  5)        5095
                Allen, Kevin P. (         kallen1)         neutral good             Paladin(  6)        6721
               Roberts, Eric J. (         erober3)         neutral good             Fighter(  7)        7765
                  Raby, Adam M. (          araby1)      lawful neutral            Magician(  9)        8814
               Frankle, Alan E. (         frankle1)        chaotic good             Fighter(  9)        8924
                Cobb, Milton T. (            cobb)      lawful neutral             Fighter(  9)        9169
              Tuveson, Eric A. (         etuves1)        chaotic evil               Thief(  7)        9245
             Nguyen, Michael D. (        mnguyen1)        chaotic good              Ranger(  9)        9490
              Shenvi, Shilpa P. (         shenvi1)        neutral good               Thief( 10)        9573
              Cloud, Clinton E. (         ccloud2)        chaotic good            Magician(  9)        9583
             Szrom, Michelle L. (         mszrom1)        chaotic good              Cleric(  9)        9660
             Mitchell, Susan M. (        smitchel)        neutral good             Fighter( 10)        9740
             Mcelvaney, Erin L. (         emcelv1)      lawful neutral              Cleric( 11)        9896
                   Fu, David E. (             dfu1)        chaotic good              Ranger( 12)       10011
```

```
Sorted by nickname:
                Joshua, Aimee (        ajoshu1)         chaotic evil              Thief(  4)        3733
            Orticke, Alecia G. (        aortic1)         chaotic good             Cleric(  4)        2048
                 Raby, Adam M. (         araby1)       lawful neutral           Magician(  9)        8814
               Moore, Brian A. (        bmoore1)          lawful evil             Ranger(  4)        4016
             Cloud, Clinton E. (        ccloud2)         chaotic good           Magician(  9)        9583
               Cobb, Milton T. (           cobb)       lawful neutral            Fighter(  9)        9169
                  Fu, David E. (           dfu1)         chaotic good             Ranger( 12)       10011
            Palewicz, David E. (        dpalew1)         chaotic good              Thief(  3)         765
            Mcelvaney, Erin L. (        emcelv1)       lawful neutral             Cleric( 11)        9896
              Roberts, Eric J. (        erober3)         neutral good            Fighter(  7)        7765
              Tuveson, Eric A. (        etuves1)         chaotic evil              Thief(  7)        9245
              Frankle, Alan E. (       frankle1)         chaotic good            Fighter(  9)        8924
             Helton, Robert L. (        helton1)         true neutral            Paladin(  3)        3034
               Allen, Kevin P. (        kallen1)         neutral good            Paladin(  6)        6721
          Macdonald, Matthew S. (       matmacd1)         chaotic good            Fighter(  5)        3797
              Baker, Matthew R. (        mbaker5)         true neutral              Thief(  4)        4313
            Napier, Matthew A. (        mnapie1)         true neutral           Magician(  5)        4539
            Nguyen, Michael D. (       mnguyen1)         chaotic good             Ranger(  9)        9490
               Seo, Maximilian (          mseo1)         chaotic evil             Ranger(  3)        3205
            Szrom, Michelle L. (        mszrom1)         chaotic good             Cleric(  9)        9660
          Rusinko, Nicholas D. (        nrusin1)          lawful good              Thief(  5)        5095
          Chandlee, Richard C. (        rchand1)          lawful evil             Ranger(  3)        3196
             Shenvi, Shilpa P. (        shenvi1)         neutral good              Thief( 10)        9573
            Mitchell, Susan M. (       smitchel)         neutral good            Fighter( 10)        9740
            Mittal, Sandeep K. (        smitta1)         chaotic good             Cleric(  2)        2706


Sorted by alignment:
              Tuveson, Eric A. (        etuves1)         chaotic evil              Thief(  7)        9245
               Seo, Maximilian (          mseo1)         chaotic evil             Ranger(  3)        3205
                 Joshua, Aimee (        ajoshu1)         chaotic evil              Thief(  4)        3733
                  Fu, David E. (           dfu1)         chaotic good             Ranger( 12)       10011
            Palewicz, David E. (        dpalew1)         chaotic good              Thief(  3)         765
            Mittal, Sandeep K. (        smitta1)         chaotic good             Cleric(  2)        2706
            Orticke, Alecia G. (        aortic1)         chaotic good             Cleric(  4)        2048
             Cloud, Clinton E. (        ccloud2)         chaotic good           Magician(  9)        9583
              Frankle, Alan E. (       frankle1)         chaotic good            Fighter(  9)        8924
          Macdonald, Matthew S. (       matmacd1)         chaotic good            Fighter(  5)        3797
            Nguyen, Michael D. (       mnguyen1)         chaotic good             Ranger(  9)        9490
            Szrom, Michelle L. (        mszrom1)         chaotic good             Cleric(  9)        9660
          Chandlee, Richard C. (        rchand1)          lawful evil             Ranger(  3)        3196
               Moore, Brian A. (        bmoore1)          lawful evil             Ranger(  4)        4016
          Rusinko, Nicholas D. (        nrusin1)          lawful good              Thief(  5)        5095
                 Raby, Adam M. (         araby1)       lawful neutral           Magician(  9)        8814
            Mcelvaney, Erin L. (        emcelv1)       lawful neutral             Cleric( 11)        9896
               Cobb, Milton T. (           cobb)       lawful neutral            Fighter(  9)        9169
               Allen, Kevin P. (        kallen1)         neutral good            Paladin(  6)        6721
            Mitchell, Susan M. (       smitchel)         neutral good            Fighter( 10)        9740
              Roberts, Eric J. (        erober3)         neutral good            Fighter(  7)        7765
             Shenvi, Shilpa P. (        shenvi1)         neutral good              Thief( 10)        9573
             Baker, Matthew R. (        mbaker5)         true neutral              Thief(  4)        4313
             Helton, Robert L. (        helton1)         true neutral            Paladin(  3)        3034
            Napier, Matthew A. (        mnapie1)         true neutral           Magician(  5)        4539
River[15]%

River[15]% exit
exit
```

```c
/* File: qsort3.c

   Demonstrating use of callback functions in qsort().
   This time we sort an array of pointers.
*/
#include <stdio.h>
#include <stdlib.h>
#include <string.h>


typedef int (* COMP_FUNC_PTR) (const void *, const void *) ;

typedef struct {
    char   realname[32] ;
    char   nickname[16] ;
    char   alignment[20] ;
    char   role[20] ;
    int    points ;
    int    level ;

} Player ;


Player records[25] = {
   {"Allen, Kevin P.", "kallen1", "neutral good", "Paladin", 6721, 6},
   {"Baker, Matthew R.", "mbaker5", "true neutral", "Thief", 4313, 4},
   {"Chandlee, Richard C.", "rchand1", "lawful evil", "Ranger", 3196, 3},
   {"Cloud, Clinton E.", "ccloud2", "chaotic good", "Magician", 9583, 9},
   {"Cobb, Milton T.", "cobb", "lawful neutral", "Fighter", 9169, 9},
   {"Frankle, Alan E.", "frankle1", "chaotic good", "Fighter", 8924, 9},
   {"Fu, David E.", "dfu1", "chaotic good", "Ranger", 10011, 12},
   {"Helton, Robert L.", "helton1", "true neutral", "Paladin", 3034, 3},
   {"Joshua, Aimee", "ajoshu1", "chaotic evil", "Thief", 3733, 4},
   {"Macdonald, Matthew S.", "matmacd1", "chaotic good", "Fighter", 3797, 5},
   {"Mcelvaney, Erin L.", "emcelv1", "lawful neutral", "Cleric", 9896, 11},
   {"Mitchell, Susan M.", "smitchel", "neutral good", "Fighter", 9740, 10},
   {"Mittal, Sandeep K.", "smitta1", "chaotic good", "Cleric", 2706, 2},
   {"Moore, Brian A.", "bmoore1", "lawful evil", "Ranger", 4016, 4},
   {"Napier, Matthew A.", "mnapie1", "true neutral", "Magician", 4539, 5},
   {"Nguyen, Michael D.", "mnguyen1", "chaotic good", "Ranger", 9490, 9},
   {"Orticke, Alecia G.", "aortic1", "chaotic good", "Cleric", 2048, 4},
   {"Palewicz, David E.", "dpalew1", "chaotic good", "Thief", 765, 3},
   {"Raby, Adam M.", "araby1", "lawful neutral", "Magician", 8814, 9},
   {"Roberts, Eric J.", "erober3", "neutral good", "Fighter", 7765, 7},
   {"Rusinko, Nicholas D.", "nrusin1", "lawful good", "Thief", 5095, 5},
   {"Seo, Maximilian", "mseo1", "chaotic evil", "Ranger", 3205, 3},
   {"Shenvi, Shilpa P.", "shenvi1", "neutral good", "Thief", 9573, 10},
   {"Szrom, Michelle L.", "mszrom1", "chaotic good", "Cleric", 9660, 9},
   {"Tuveson, Eric A.", "etuves1", "chaotic evil", "Thief", 9245, 7}
} ;



void PrintPlayer(Player *p) {

   printf("%32s (%16s)  %20s  %20s(%3d)  %10d\n",
      p->realname, p->nickname, p->alignment, p->role, p->level,
      p->points) ;
}
```

```
int byPoints(Player **p1, Player **p2) {
   return (*p1)->points - (*p2)->points ;
}

int byNickname(Player **p1, Player **p2) {
   return strcmp((*p1)->nickname, (*p2)->nickname) ;
}

int byAlignment(Player **p1, Player **p2) {
   return strcmp((*p1)->alignment, (*p2)->alignment) ;
}

int main () {

   int i ;
   Player *rec_ptrs[25] ;

   for (i = 0 ; i < 25 ; i++) {
      rec_ptrs[i] = &records[i] ;
   }


   printf("Original list:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(rec_ptrs[i]) ;
   }


   qsort(rec_ptrs, 25, sizeof(Player *), (COMP_FUNC_PTR) &byPoints) ;

   printf("\n\nSorted by points:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(rec_ptrs[i]) ;
   }


   qsort(rec_ptrs, 25, sizeof(Player *), (COMP_FUNC_PTR) &byNickname) ;

   printf("\n\nSorted by nickname:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(rec_ptrs[i]) ;
   }


   qsort(rec_ptrs, 25, sizeof(Player *), (COMP_FUNC_PTR) &byAlignment) ;

   printf("\n\nSorted by alignment:\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(rec_ptrs[i]) ;
   }

   printf("\n\nOriginal list (again):\n") ;
   for (i = 0 ; i < 25 ; i++) {
      PrintPlayer(&records[i]) ;
   }

   return 0 ;
}
```

```
Script started on Wed Oct 17 23:15:52 2012
River[16]% gcc -Wall qsort3.c
River[17]%
River[17]% ./a.out
Original list:
                Allen, Kevin P. (         kallen1)         neutral good             Paladin(  6)        6721
              Baker, Matthew R. (         mbaker5)         true neutral               Thief(  4)        4313
           Chandlee, Richard C. (         rchand1)          lawful evil              Ranger(  3)        3196
              Cloud, Clinton E. (         ccloud2)        chaotic good            Magician(  9)        9583
                Cobb, Milton T. (            cobb)      lawful neutral             Fighter(  9)        9169
               Frankle, Alan E. (         frankle1)        chaotic good             Fighter(  9)        8924
                   Fu, David E. (             dfu1)        chaotic good              Ranger( 12)       10011
              Helton, Robert L. (         helton1)         true neutral             Paladin(  3)        3034
                  Joshua, Aimee (         ajoshu1)        chaotic evil               Thief(  4)        3733
          Macdonald, Matthew S. (        matmacd1)        chaotic good             Fighter(  5)        3797
             Mcelvaney, Erin L. (         emcelv1)      lawful neutral              Cleric( 11)        9896
             Mitchell, Susan M. (        smitchel)        neutral good             Fighter( 10)        9740
             Mittal, Sandeep K. (         smitta1)        chaotic good              Cleric(  2)        2706
                Moore, Brian A. (         bmoore1)          lawful evil              Ranger(  4)        4016
             Napier, Matthew A. (         mnapie1)         true neutral            Magician(  5)        4539
             Nguyen, Michael D. (        mnguyen1)        chaotic good              Ranger(  9)        9490
             Orticke, Alecia G. (         aortic1)        chaotic good              Cleric(  4)        2048
             Palewicz, David E. (         dpalew1)        chaotic good               Thief(  3)         765
                  Raby, Adam M. (          araby1)      lawful neutral            Magician(  9)        8814
               Roberts, Eric J. (         erober3)        neutral good             Fighter(  7)        7765
            Rusinko, Nicholas D. (         nrusin1)          lawful good               Thief(  5)        5095
                 Seo, Maximilian (           mseo1)        chaotic evil              Ranger(  3)        3205
               Shenvi, Shilpa P. (         shenvi1)        neutral good               Thief( 10)        9573
             Szrom, Michelle L. (         mszrom1)        chaotic good              Cleric(  9)        9660
               Tuveson, Eric A. (         etuves1)        chaotic evil               Thief(  7)        9245


Sorted by points:
             Palewicz, David E. (         dpalew1)        chaotic good               Thief(  3)         765
             Orticke, Alecia G. (         aortic1)        chaotic good              Cleric(  4)        2048
             Mittal, Sandeep K. (         smitta1)        chaotic good              Cleric(  2)        2706
              Helton, Robert L. (         helton1)         true neutral             Paladin(  3)        3034
           Chandlee, Richard C. (         rchand1)          lawful evil              Ranger(  3)        3196
                 Seo, Maximilian (           mseo1)        chaotic evil              Ranger(  3)        3205
                   Joshua, Aimee (         ajoshu1)        chaotic evil               Thief(  4)        3733
          Macdonald, Matthew S. (        matmacd1)        chaotic good             Fighter(  5)        3797
                Moore, Brian A. (         bmoore1)          lawful evil              Ranger(  4)        4016
              Baker, Matthew R. (         mbaker5)         true neutral               Thief(  4)        4313
             Napier, Matthew A. (         mnapie1)         true neutral            Magician(  5)        4539
            Rusinko, Nicholas D. (         nrusin1)          lawful good               Thief(  5)        5095
                 Allen, Kevin P. (         kallen1)         neutral good             Paladin(  6)        6721
               Roberts, Eric J. (         erober3)        neutral good             Fighter(  7)        7765
                  Raby, Adam M. (          araby1)      lawful neutral            Magician(  9)        8814
               Frankle, Alan E. (         frankle1)        chaotic good             Fighter(  9)        8924
                Cobb, Milton T. (            cobb)      lawful neutral             Fighter(  9)        9169
              Tuveson, Eric A. (         etuves1)        chaotic evil               Thief(  7)        9245
             Nguyen, Michael D. (        mnguyen1)        chaotic good              Ranger(  9)        9490
              Shenvi, Shilpa P. (         shenvi1)        neutral good               Thief( 10)        9573
              Cloud, Clinton E. (         ccloud2)        chaotic good            Magician(  9)        9583
             Szrom, Michelle L. (         mszrom1)        chaotic good              Cleric(  9)        9660
             Mitchell, Susan M. (        smitchel)        neutral good             Fighter( 10)        9740
             Mcelvaney, Erin L. (         emcelv1)      lawful neutral              Cleric( 11)        9896
                   Fu, David E. (             dfu1)        chaotic good              Ranger( 12)       10011
```

Sorted by nickname:

Joshua, Aimee	ajoshu1	chaotic evil	Thief(4)	3733
Orticke, Alecia G.	aortic1	chaotic good	Cleric(4)	2048
Raby, Adam M.	araby1	lawful neutral	Magician(9)	8814
Moore, Brian A.	bmoore1	lawful evil	Ranger(4)	4016
Cloud, Clinton E.	ccloud2	chaotic good	Magician(9)	9583
Cobb, Milton T.	cobb	lawful neutral	Fighter(9)	9169
Fu, David E.	dfu1	chaotic good	Ranger(12)	10011
Palewicz, David E.	dpalew1	chaotic good	Thief(3)	765
Mcelvaney, Erin L.	emcelv1	lawful neutral	Cleric(11)	9896
Roberts, Eric J.	erober3	neutral good	Fighter(7)	7765
Tuveson, Eric A.	etuves1	chaotic evil	Thief(7)	9245
Frankle, Alan E.	frankle1	chaotic good	Fighter(9)	8924
Helton, Robert L.	helton1	true neutral	Paladin(3)	3034
Allen, Kevin P.	kallen1	neutral good	Paladin(6)	6721
Macdonald, Matthew S.	matmacd1	chaotic good	Fighter(5)	3797
Baker, Matthew R.	mbaker5	true neutral	Thief(4)	4313
Napier, Matthew A.	mnapie1	true neutral	Magician(5)	4539
Nguyen, Michael D.	mnguyen1	chaotic good	Ranger(9)	9490
Seo, Maximilian	mseo1	chaotic evil	Ranger(3)	3205
Szrom, Michelle L.	mszrom1	chaotic good	Cleric(9)	9660
Rusinko, Nicholas D.	nrusin1	lawful good	Thief(5)	5095
Chandlee, Richard C.	rchand1	lawful evil	Ranger(3)	3196
Shenvi, Shilpa P.	shenvi1	neutral good	Thief(10)	9573
Mitchell, Susan M.	smitchel	neutral good	Fighter(10)	9740
Mittal, Sandeep K.	smitta1	chaotic good	Cleric(2)	2706

Sorted by alignment:

Tuveson, Eric A.	etuves1	chaotic evil	Thief(7)	9245
Seo, Maximilian	mseo1	chaotic evil	Ranger(3)	3205
Joshua, Aimee	ajoshu1	chaotic evil	Thief(4)	3733
Fu, David E.	dfu1	chaotic good	Ranger(12)	10011
Palewicz, David E.	dpalew1	chaotic good	Thief(3)	765
Mittal, Sandeep K.	smitta1	chaotic good	Cleric(2)	2706
Orticke, Alecia G.	aortic1	chaotic good	Cleric(4)	2048
Cloud, Clinton E.	ccloud2	chaotic good	Magician(9)	9583
Frankle, Alan E.	frankle1	chaotic good	Fighter(9)	8924
Macdonald, Matthew S.	matmacd1	chaotic good	Fighter(5)	3797
Nguyen, Michael D.	mnguyen1	chaotic good	Ranger(9)	9490
Szrom, Michelle L.	mszrom1	chaotic good	Cleric(9)	9660
Chandlee, Richard C.	rchand1	lawful evil	Ranger(3)	3196
Moore, Brian A.	bmoore1	lawful evil	Ranger(4)	4016
Rusinko, Nicholas D.	nrusin1	lawful good	Thief(5)	5095
Raby, Adam M.	araby1	lawful neutral	Magician(9)	8814
Mcelvaney, Erin L.	emcelv1	lawful neutral	Cleric(11)	9896
Cobb, Milton T.	cobb	lawful neutral	Fighter(9)	9169
Allen, Kevin P.	kallen1	neutral good	Paladin(6)	6721
Mitchell, Susan M.	smitchel	neutral good	Fighter(10)	9740
Roberts, Eric J.	erober3	neutral good	Fighter(7)	7765
Shenvi, Shilpa P.	shenvi1	neutral good	Thief(10)	9573
Baker, Matthew R.	mbaker5	true neutral	Thief(4)	4313
Helton, Robert L.	helton1	true neutral	Paladin(3)	3034
Napier, Matthew A.	mnapie1	true neutral	Magician(5)	4539

```
Original list (again):
                Allen, Kevin P. (         kallen1)          neutral good              Paladin(  6)        6721
               Baker, Matthew R. (         mbaker5)          true neutral                Thief(  4)        4313
            Chandlee, Richard C. (         rchand1)           lawful evil               Ranger(  3)        3196
               Cloud, Clinton E. (         ccloud2)          chaotic good             Magician(  9)        9583
                 Cobb, Milton T. (            cobb)        lawful neutral              Fighter(  9)        9169
                Frankle, Alan E. (         frankle1)          chaotic good              Fighter(  9)        8924
                    Fu, David E. (             dfu1)          chaotic good               Ranger( 12)       10011
               Helton, Robert L. (         helton1)          true neutral              Paladin(  3)        3034
                   Joshua, Aimee (         ajoshu1)          chaotic evil                Thief(  4)        3733
           Macdonald, Matthew S. (        matmacd1)          chaotic good              Fighter(  5)        3797
              Mcelvaney, Erin L. (         emcelv1)        lawful neutral               Cleric( 11)        9896
              Mitchell, Susan M. (        smitchel)          neutral good              Fighter( 10)        9740
              Mittal, Sandeep K. (         smitta1)          chaotic good               Cleric(  2)        2706
                 Moore, Brian A. (         bmoore1)           lawful evil               Ranger(  4)        4016
              Napier, Matthew A. (         mnapie1)          true neutral             Magician(  5)        4539
              Nguyen, Michael D. (        mnguyen1)          chaotic good               Ranger(  9)        9490
              Orticke, Alecia G. (         aortic1)          chaotic good               Cleric(  4)        2048
              Palewicz, David E. (         dpalew1)          chaotic good                Thief(  3)         765
                   Raby, Adam M. (          araby1)        lawful neutral             Magician(  9)        8814
                Roberts, Eric J. (         erober3)          neutral good              Fighter(  7)        7765
            Rusinko, Nicholas D. (         nrusin1)           lawful good                Thief(  5)        5095
                 Seo, Maximilian (           mseo1)          chaotic evil               Ranger(  3)        3205
               Shenvi, Shilpa P. (         shenvi1)          neutral good                Thief( 10)        9573
              Szrom, Michelle L. (         mszrom1)          chaotic good               Cleric(  9)        9660
                Tuveson, Eric A. (         etuves1)          chaotic evil                Thief(  7)        9245
River[18]%
River[18]% exit
exit

Script done on Wed Oct 17 23:16:03 2012
```

NEXT TIME

- **Polymorphism in C?**