"The C Programming Language", 2nd edition, Kernighan and Ritchie

Answer to Exercise 1-1

Run the "hello, world" program on your system. Experiment with leaving out parts of the program, to see what error messages you get.

Murphy's Law dictates that there is no single correct answer to the very first exercise in the book. Oh well. Here's a "hello world" program:

```
#include <stdio.h>

int main(void)
{
  printf("hello, world\n");
  return 0;
}
```

As you can see, I've added a `return` statement, because `main` always returns `int`, and it's good style to show this explicitly.

Answer to Exercise 1-2

Experiment to find out what happens when `printf` 's argument string contains \c, where c is some character not listed above.

By 'above', the question is referring to:
`\n` (newline)
`\t` (tab)
`\b` (backspace)
`\"` (double quote)
\\ (backslash) We have to tread carefully here, because using a non-specified escape sequence invokes undefined behaviour. The following program attempts to demonstrate all the legal escape sequences, not including the ones already shown (except `\n` , which I actually need in the program), and not including hexadecimal and octal escape sequences.

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

```c
int main(void)
{
  printf("Audible or visual alert. \a\n");
  printf("Form feed. \f\n");
  printf("This escape, \r, moves the active position to the initial
position of the current line.\n");
  printf("Vertical tab \v is tricky, as its behaviour is unspecified under
certain conditions.\n");

  return 0;
}
```

Answer to Exercise 1-3

Modify the temperature conversion program to print a heading above the table.

```c
#include <stdio.h>

int main(void)
{
  float fahr, celsius;
  int lower, upper, step;

  lower = 0;
  upper = 300;
  step = 20;

  printf("F    C\n\n");
  fahr = lower;
  while(fahr <= upper)
  {
    celsius = (5.0 / 9.0) * (fahr - 32.0);
    printf("%3.0f %6.1f\n", fahr, celsius);
    fahr = fahr + step;
  }
  return 0;
}
```

Answer to Exercise 1-4

Write a program to print the corresponding Celsius to Fahrenheit table.

```c
#include <stdio.h>

int main(void)
{
  float fahr, celsius;
  int lower, upper, step;

  lower = 0;
  upper = 300;
  step = 20;

  printf("C    F\n\n");
  celsius = lower;
  while(celsius <= upper)
  {
    fahr = (9.0/5.0) * celsius + 32.0;
    printf("%3.0f %6.1f\n", celsius, fahr);
    celsius = celsius + step;
  }
  return 0;
}
```

Answer to Exercise 1-5

Modify the temperature conversion program to print the table in reverse order, that is, from 300 degrees to 0.

This version uses a `while` loop:

```c
#include <stdio.h>

int main(void)
{
  float fahr, celsius;
  int lower, upper, step;

  lower = 0;
  upper = 300;
  step = 20;

  printf("C    F\n\n");
  celsius = upper;
  while(celsius >= lower)
  {
```

```
    fahr = (9.0/5.0) * celsius + 32.0;
    printf("%3.0f %6.1f\n", celsius, fahr);
    celsius = celsius - step;
  }
  return 0;
}
```

This version uses a `for` loop:

```
#include <stdio.h>

int main(void)
{
  float fahr, celsius;
  int lower, upper, step;

  lower = 0;
  upper = 300;
  step = 20;

  printf("C    F\n\n");
  for(celsius = upper; celsius >= lower; celsius = celsius - step)
  {
    fahr = (9.0/5.0) * celsius + 32.0;
    printf("%3.0f %6.1f\n", celsius, fahr);
  }
  return 0;
}
```

Chris Sidi notes that Section 1.3 Has a short For statement example, and "Based on that example, I think the solution to 1.5:
a) should do fahr to celsius conversion (whereas the solutions on your page do celsius to fahr)
b) should be similar to the example and as small." He offers this solution:

```
#include <stdio.h>

/* print Fahrenheit-Celsius table */
int
main()
{
    int fahr;
```

```
    for (fahr = 300; fahr >= 0; fahr = fahr - 20)
          printf("%3d %6.1f\n", fahr, (5.0/9.0)*(fahr-32));

  return 0;
}
```

Answer to Exercise 1-6

Verify that the expression `getchar() != EOF` is 0 or 1.

```
/* This program prompts for input, and then captures a character
 * from the keyboard. If EOF is signalled (typically through a
 * control-D or control-Z character, though not necessarily),
 * the program prints 0. Otherwise, it prints 1.
 *
 * If your input stream is buffered (and it probably is), then
 * you will need to press the ENTER key before the program will
 * respond.
 */

#include <stdio.h>

int main(void)
{
  printf("Press a key. ENTER would be nice :-)\n\n");
  printf("The expression getchar() != EOF evaluates to %d\n", getchar() !=
EOF);
  return 0;
}
```

Answer to Exercise 1-7

Write a program to print the value of `EOF` .

```
#include <stdio.h>

int main(void)
```

```
{
  printf("The value of EOF is %d\n\n", EOF);

  return 0;
}
```

Exercise 1-8

Write a program to count blanks, tabs, and newlines.

```
#include <stdio.h>

int main(void)
{
  int blanks, tabs, newlines;
  int c;
  int done = 0;
  int lastchar = 0;

  blanks = 0;
  tabs = 0;
  newlines = 0;

  while(done == 0)
  {
    c = getchar();

    if(c == ' ')
      ++blanks;

    if(c == '\t')
      ++tabs;

    if(c == '\n')
      ++newlines;

    if(c == EOF)
    {
      if(lastchar != '\n')
      {
        ++newlines; /* this is a bit of a semantic stretch, but it copes
                     * with implementations where a text file might not
                     * end with a newline. Thanks to Jim Stad for pointing
```

```
                * this out.
                */
      }
      done = 1;
    }
    lastchar = c;
  }

  printf("Blanks: %d\nTabs: %d\nLines: %d\n", blanks, tabs, newlines);
  return 0;
}
```

Exercise 1-9

Write a program to copy its input to its output, replacing each string of one or more blanks by a single blank.

```
#include <stdio.h>

int main(void)
{
  int c;
  int inspace;

  inspace = 0;
  while((c = getchar()) != EOF)
  {
    if(c == ' ')
    {
      if(inspace == 0)
      {
        inspace = 1;
        putchar(c);
      }
    }

    /* We haven't met 'else' yet, so we have to be a little clumsy */
    if(c != ' ')
    {
      inspace = 0;
      putchar(c);
    }
  }
```

```
  return 0;
}
```

Chris Sidi writes: "instead of having an "inspace" boolean, you can keep track of the previous character and see if both the current character and previous character are spaces:"

```
#include <stdio.h>

/* count lines in input */
int
main()
{
	int c, pc; /* c = character, pc = previous character */

	/* set pc to a value that wouldn't match any character, in case
	this program is ever modified to get rid of multiples of other
	characters */

	pc = EOF;

	while ((c = getchar()) != EOF) {
		if (c == ' ')
			if (pc != ' ')  /* or if (pc != c) */
				putchar(c);

		/* We haven't met 'else' yet, so we have to be a little clumsy
*/
		if (c != ' ')
			putchar(c);
		pc = c;
	}

	return 0;
}
```

Stig writes: "I am hiding behind the fact that `break` is mentioned in the introduction"!

```
#include <stdio.h>

int main(void)
{
        int c;
        while ((c = getchar()) != EOF) {
                 if (c == ' ') {
                        putchar(c);
                        while((c = getchar()) == ' ' && c != EOF)
                                ;
                }
                if (c == EOF)
                        break; /* the break keyword is mentioned
                                * in the introduction...
                                * */

                putchar(c);
        }
        return 0;
}
```

Exercise 1-10

Write a program to copy its input to its output, replacing each tab by `\t` , each backspace by `\b` , and each backslash by `\\` . This makes tabs and backspaces visible in an unambiguous way.

Category 0

Gregory Pietsch pointed out that my solution was actually Category 1. He was quite right. Better still, he was kind enough to submit a Category 0 solution himself. Here it is:

```
/* Gregory Pietsch <gkp1@flash.net> */

/*
 * Here's my attempt at a Category 0 version of 1-10.
 *
 * Gregory Pietsch
 */
```

```c
#include <stdio.h>

int main()
{
    int c, d;

    while ( (c=getchar()) != EOF) {
        d = 0;
        if (c == '\\') {
            putchar('\\');
            putchar('\\');
            d = 1;
        }
        if (c == '\t') {
            putchar('\\');
            putchar('t');
            d = 1;
        }
        if (c == '\b') {
            putchar('\\');
            putchar('b');
            d = 1;
        }
        if (d == 0)
            putchar(c);
    }
    return 0;
}
```

Category 1

This solution, which I wrote myself, is the sadly discredited Cat 0 answer which has found a new lease of life in Category 1.

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

```c
#define ESC_CHAR '\\'

int main(void)
{
  int c;

  while((c = getchar()) != EOF)
  {
    switch(c)
    {
      case '\b':
        /* The OS on which I tested this (NT) intercepts \b characters.
*/
        putchar(ESC_CHAR);
        putchar('b');
        break;
      case '\t':
        putchar(ESC_CHAR);
        putchar('t');
        break;
      case ESC_CHAR:
        putchar(ESC_CHAR);
        putchar(ESC_CHAR);
        break;
      default:
        putchar(c);
        break;
    }
  }
  return 0;
}
```

Exercise 1-11

How would you test the word count program? What kinds of input are most likely to uncover bugs if there are any?

It sounds like they are really trying to get the programmers to learn how to do a unit test. I would submit the following:

0. input file contains zero words
1. input file contains 1 enormous word without any newlines
2. input file contains all white space without newlines
3. input file contains 66000 newlines
4. input file contains word/{huge sequence of whitespace of different kinds}/word

5. input file contains 66000 single letter words, 66 to the line
6. input file contains 66000 words without any newlines
7. input file is `/usr/dict` contents (or equivalent)
8. input file is full collection of moby words
9. input file is binary (e.g. its own executable)
10. input file is `/dev/nul` (or equivalent)

66000 is chosen to check for integral overflow on small integer machines.

Dann suggests a followup exercise 1-11a: write a program to generate inputs (0,1,2,3,4,5,6)

I guess it was inevitable that I'd receive a solution for this followup exercise! Here is Gregory Pietsch's program to generate Dann's suggested inputs:

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

int main(void)
{
    FILE *f;
    unsigned long i;
    static char *ws = " \f\t\v";
    static char *al = "abcdefghijklmnopqrstuvwxyz";
    static char *i5 = "a b c d e f g h i j k l m "
                  "n o p q r s t u v w x y z "
                  "a b c d e f g h i j k l m "
                  "n o p q r s t u v w x y z "
                  "a b c d e f g h i j k l m "
                  "n\n";

    /* Generate the following: */
    /* 0. input file contains zero words */
    f = fopen("test0", "w");
    assert(f != NULL);
    fclose(f);

    /* 1. input file contains 1 enormous word without any newlines */
    f = fopen("test1", "w");
```

```
assert(f != NULL);
for (i = 0; i < ((66000ul / 26) + 1); i++)
   fputs(al, f);
fclose(f);

/* 2. input file contains all white space without newlines */
f = fopen("test2", "w");
assert(f != NULL);
for (i = 0; i < ((66000ul / 4) + 1); i++)
   fputs(ws, f);
fclose(f);

/* 3. input file contains 66000 newlines */
f = fopen("test3", "w");
assert(f != NULL);
for (i = 0; i < 66000; i++)
   fputc('\n', f);
fclose(f);

/* 4. input file contains word/
 *    {huge sequence of whitespace of different kinds}
 *    /word
 */
f = fopen("test4", "w");
assert(f != NULL);
fputs("word", f);
for (i = 0; i < ((66000ul / 26) + 1); i++)
   fputs(ws, f);
fputs("word", f);
fclose(f);

/* 5. input file contains 66000 single letter words,
 *    66 to the line
 */
f = fopen("test5", "w");
assert(f != NULL);
for (i = 0; i < 1000; i++)
   fputs(i5, f);
fclose(f);

/* 6. input file contains 66000 words without any newlines */
f = fopen("test6", "w");
assert(f != NULL);
for (i = 0; i < 66000; i++)
```

```
        fputs("word ", f);
    fclose(f);

    return 0;
}
```

Exercise 1-12

Write a program that prints its input one word per line.

```
#include <stdio.h>
int main(void)
{
  int c;
  int inspace;

  inspace = 0;
  while((c = getchar()) != EOF)
  {
    if(c == ' ' || c == '\t' || c == '\n')
    {
      if(inspace == 0)
      {
        inspace = 1;
        putchar('\n');
      }
      /* else, don't print anything */
    }
    else
    {
      inspace = 0;
      putchar(c);
    }
  }
  return 0;
}
```

Exercise 1-13

Write a program to print a histogram of the lengths of words in its input. It is easy to draw the histogram with the bars horizontal; a vertical orientation is more challenging.

```c
/* This program was the subject of a thread in comp.lang.c, because of the way it handled EOF.
 * The complaint was that, in the event of a text file's last line not ending with a newline,
 * this program would not count the last word. I objected somewhat to this complaint, on the
 * grounds that "if it hasn't got a newline at the end of each line, it isn't a text file".
 *
 * These grounds turned out to be incorrect. Whether such a file is a text file turns out to
 * be implementation-defined. I'd had a go at checking my facts, and had - as it turns out -
 * checked the wrong facts! (sigh)
 *
 * It cost me an extra variable. It turned out that the least disturbing way to modify the
 * program (I always look for the least disturbing way) was to replace the traditional
 * while((c = getchar()) != EOF) with an EOF test actually inside the loop body. This meant
 * adding an extra variable, but is undoubtedly worth the cost, because it means the program
 * can now handle other people's text files as well as my own. As Ben Pfaff said at the
 * time, "Be liberal in what you accept, strict in what you produce". Sound advice.
 *
 * The new version has, of course, been tested, and does now accept text files not ending in
 * newlines.
 *
 * I have, of course, regenerated the sample output from this program. Actually, there's no
 * "of course" about it - I nearly forgot.
 */

#include <stdio.h>

#define MAXWORDLEN 10

int main(void)
{
  int c;
```

```
int inspace = 0;
long lengtharr[MAXWORDLEN + 1];
int wordlen = 0;

int firstletter = 1;
long thisval = 0;
long maxval = 0;
int thisidx = 0;
int done = 0;

for(thisidx = 0; thisidx <= MAXWORDLEN; thisidx++)
{
  lengtharr[thisidx] = 0;
}

while(done == 0)
{
  c = getchar();

  if(c == ' ' || c == '\t' || c == '\n' || c == EOF)
  {
    if(inspace == 0)
    {
      firstletter = 0;
      inspace = 1;

      if(wordlen <= MAXWORDLEN)
      {
        if(wordlen > 0)
        {
          thisval = ++lengtharr[wordlen - 1];
          if(thisval > maxval)
          {
            maxval = thisval;
          }
        }
      }
      else
      {
        thisval = ++lengtharr[MAXWORDLEN];
        if(thisval > maxval)
        {
          maxval = thisval;
        }
```

```
      }
    }
    if(c == EOF)
    {
      done = 1;
    }
  }
  else
  {
    if(inspace == 1 || firstletter == 1)
    {
      wordlen = 0;
      firstletter = 0;
      inspace = 0;
    }
    ++wordlen;
  }
}

for(thisval = maxval; thisval > 0; thisval--)
{
  printf("%4d  | ", thisval);
  for(thisidx = 0; thisidx <= MAXWORDLEN; thisidx++)
  {
    if(lengtharr[thisidx] >= thisval)
    {
      printf("*  ");
    }
    else
    {
      printf("   ");
    }
  }
  printf("\n");
}
printf("     +");
for(thisidx = 0; thisidx <= MAXWORDLEN; thisidx++)
{
  printf("---");
}
printf("\n      ");
for(thisidx = 0; thisidx < MAXWORDLEN; thisidx++)
{
  printf("%2d ", thisidx + 1);
```

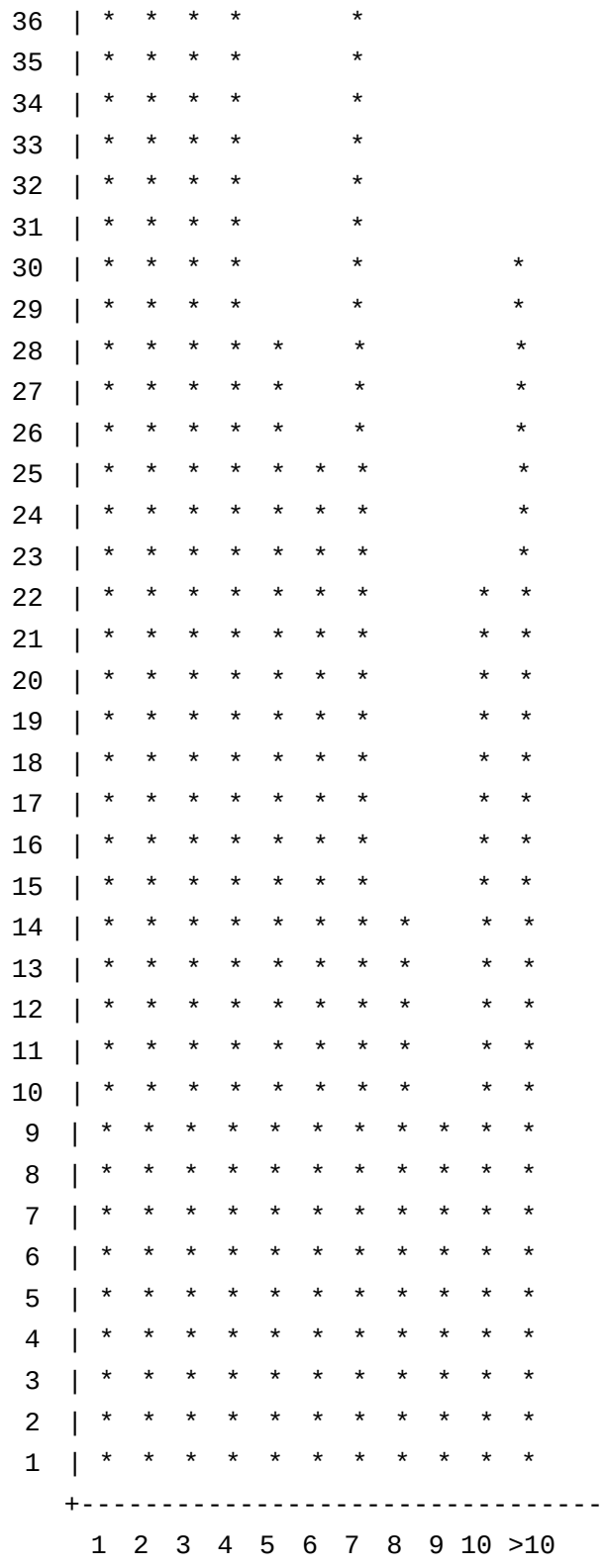
```
  }
  printf(">%d\n", MAXWORDLEN);

  return 0;
}
```

Here's the output of the program when given its own source as input:

```
 113  | *
 112  | *
 111  | *
 110  | *
 109  | *
 108  | *
 107  | *
 106  | *
 105  | *
 104  | *
 103  | *
 102  | *
 101  | *
 100  | *
  99  | *
  98  | *
  97  | *
  96  | *
  95  | *
  94  | *  *
  93  | *  *
  92  | *  *
  91  | *  *
  90  | *  *
  89  | *  *
  88  | *  *
  87  | *  *
  86  | *  *
  85  | *  *
  84  | *  *
  83  | *  *
  82  | *  *
  81  | *  *
```

```
80  | *  *
79  | *  *
78  | *  *
77  | *  *
76  | *  *
75  | *  *
74  | *  *
73  | *  *
72  | *  *
71  | *  *
70  | *  *
69  | *  *
68  | *  *
67  | *  *
66  | *  *
65  | *  *
64  | *  *
63  | *  *  *
62  | *  *  *
61  | *  *  *
60  | *  *  *
59  | *  *  *
58  | *  *  *
57  | *  *  *
56  | *  *  *
55  | *  *  *
54  | *  *  *
53  | *  *  *
52  | *  *  *  *
51  | *  *  *  *
50  | *  *  *  *
49  | *  *  *  *
48  | *  *  *  *
47  | *  *  *  *
46  | *  *  *  *
45  | *  *  *  *
44  | *  *  *  *
43  | *  *  *  *       *
42  | *  *  *  *       *
41  | *  *  *  *       *
40  | *  *  *  *       *
39  | *  *  *  *       *
38  | *  *  *  *       *
37  | *  *  *  *       *
```



Exercise 1-14

Write a program to print a histogram of the frequencies of different characters in its input.

Naturally, I've gone for a vertical orientation to match exercise 13. I had some difficulty ensuring that the printing of the X-axis didn't involve cheating. I wanted to display each character if possible, but that would have meant using isprint(), which we haven't yet met. So I decided to display the value of the character instead. (The results below show the output on an ASCII system - naturally, a run on an EBCDIC machine would give different numbers.) I had to jump through a few hoops to avoid using the % operator which, again, we haven't yet met at this point in the text.

```
#include <stdio.h>

/* NUM_CHARS should really be CHAR_MAX but K&R haven't covered that at
this stage in the book */
#define NUM_CHARS 256

int main(void)
{
  int c;
  long freqarr[NUM_CHARS + 1];

  long thisval = 0;
  long maxval = 0;
  int thisidx = 0;

  for(thisidx = 0; thisidx <= NUM_CHARS; thisidx++)
  {
    freqarr[thisidx] = 0;
  }

  while((c = getchar()) != EOF)
  {
    if(c < NUM_CHARS)
    {
      thisval = ++freqarr[c];
      if(thisval > maxval)
      {
        maxval = thisval;
      }
    }
    else
```

```
  {
    thisval = ++freqarr[NUM_CHARS];
    if(thisval > maxval)
    {
      maxval = thisval;
    }
  }
}

for(thisval = maxval; thisval > 0; thisval--)
{
  printf("%4d  |", thisval);
  for(thisidx = 0; thisidx <= NUM_CHARS; thisidx++)
  {
    if(freqarr[thisidx] >= thisval)
    {
      printf("*");
    }
    else if(freqarr[thisidx] > 0)
    {
      printf(" ");
    }
  }
  printf("\n");
}
printf("     +");
for(thisidx = 0; thisidx <= NUM_CHARS; thisidx++)
{
  if(freqarr[thisidx] > 0)
  {
    printf("-");
  }
}
printf("\n      ");
for(thisidx = 0; thisidx < NUM_CHARS; thisidx++)
{
  if(freqarr[thisidx] > 0)
  {
    printf("%d", thisidx / 100);
  }
}
printf("\n      ");
for(thisidx = 0; thisidx < NUM_CHARS; thisidx++)
{
```

```
    if(freqarr[thisidx] > 0)
    {
      printf("%d", (thisidx - (100 * (thisidx / 100))) / 10 );
    }
  }
  printf("\n      ");
  for(thisidx = 0; thisidx < NUM_CHARS; thisidx++)
  {
    if(freqarr[thisidx] > 0)
    {
      printf("%d", thisidx - (10 * (thisidx / 10)));
    }
  }
  if(freqarr[NUM_CHARS] > 0)
  {
    printf(">%d\n", NUM_CHARS);
  }

  printf("\n");

  return 0;
}
```

Here's the output of the program when given its own source as input:

```
 474  | *
 473  | *
 472  | *
 471  | *
 470  | *
 469  | *
 468  | *
 467  | *
 466  | *
 465  | *
 464  | *
 463  | *
 462  | *
 461  | *
 460  | *
 459  | *
```

458 | *
457 | *
456 | *
455 | *
454 | *
453 | *
452 | *
451 | *
450 | *
449 | *
448 | *
447 | *
446 | *
445 | *
444 | *
443 | *
442 | *
441 | *
440 | *
439 | *
438 | *
437 | *
436 | *
435 | *
434 | *
433 | *
432 | *
431 | *
430 | *
429 | *
428 | *
427 | *
426 | *
425 | *
424 | *
423 | *
422 | *
421 | *
420 | *
419 | *
418 | *
417 | *
416 | *
415 | *

414 | *
413 | *
412 | *
411 | *
410 | *
409 | *
408 | *
407 | *
406 | *
405 | *
404 | *
403 | *
402 | *
401 | *
400 | *
399 | *
398 | *
397 | *
396 | *
395 | *
394 | *
393 | *
392 | *
391 | *
390 | *
389 | *
388 | *
387 | *
386 | *
385 | *
384 | *
383 | *
382 | *
381 | *
380 | *
379 | *
378 | *
377 | *
376 | *
375 | *
374 | *
373 | *
372 | *
371 | *

```
370  | *
369  | *
368  | *
367  | *
366  | *
365  | *
364  | *
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```

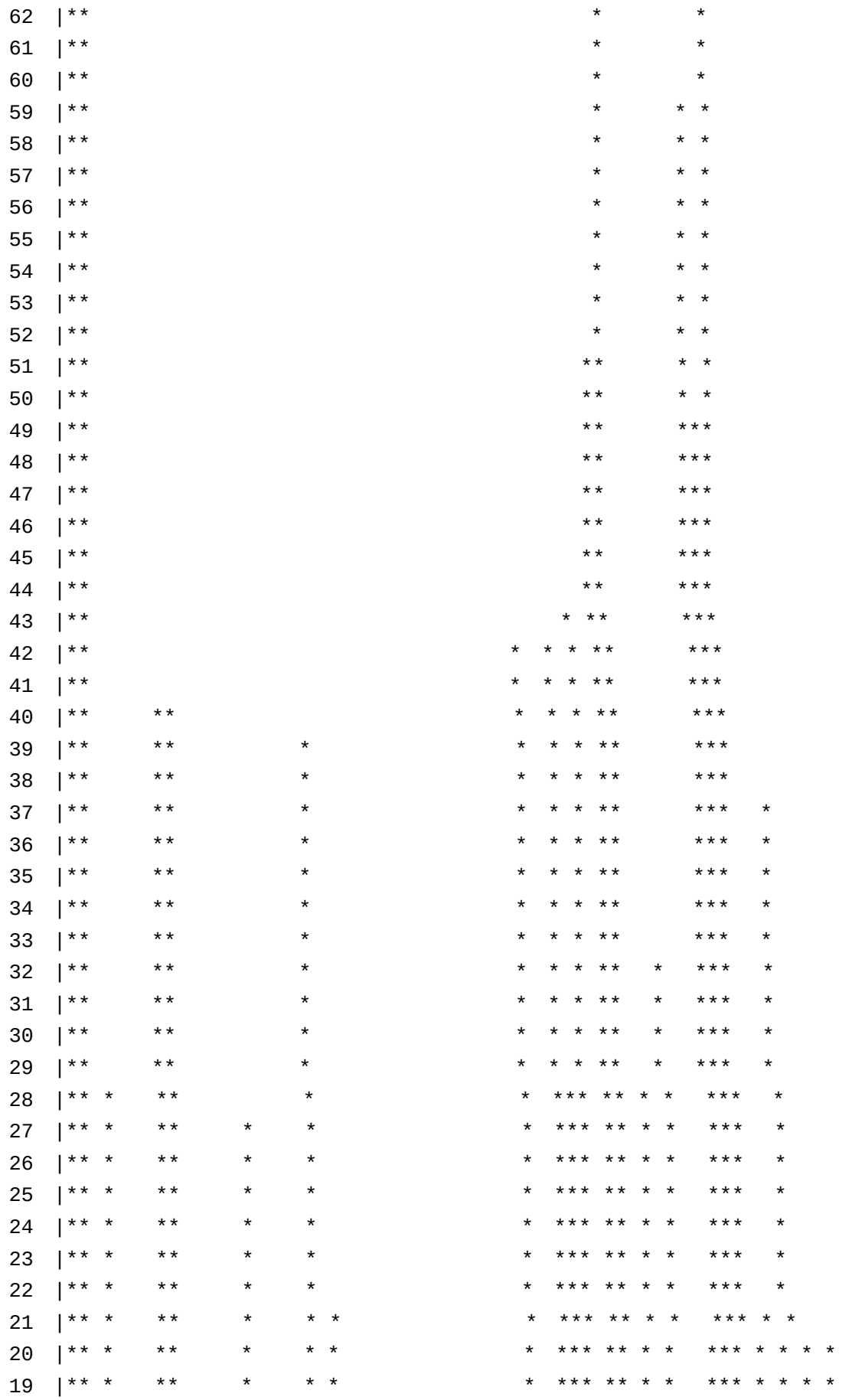

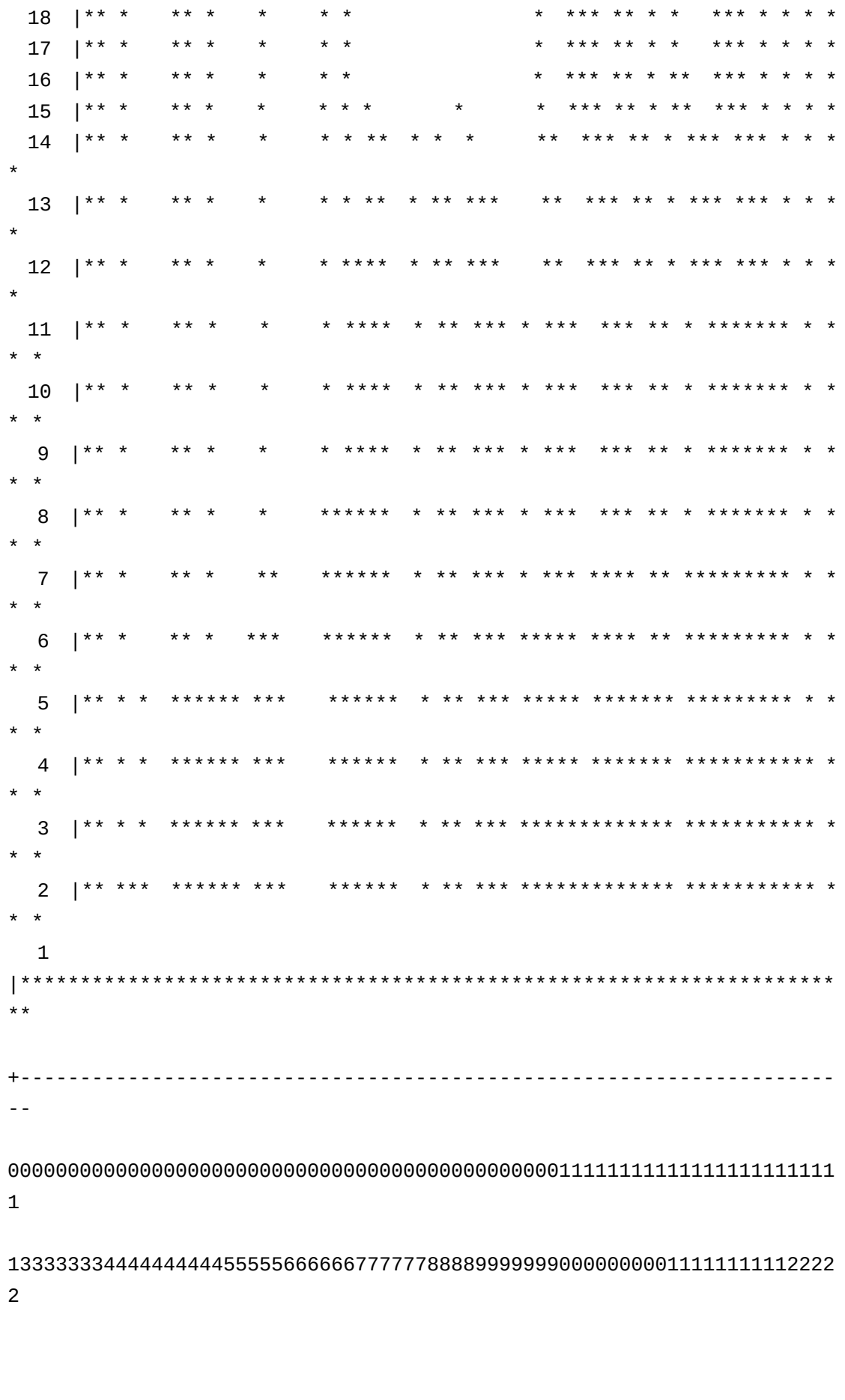

```
023457890123456789023490125790257892358123578901234578901234567890134
5
```

Answer to Exercise 1-15, page 27

Rewrite the temperature conversion program of Section 1.2 to use a function for conversion.

```c
#include <stdio.h>

float FtoC(float f)
{
  float c;
  c = (5.0 / 9.0) * (f - 32.0);
  return c;
}

int main(void)
{
  float fahr, celsius;
  int lower, upper, step;

  lower = 0;
  upper = 300;
  step = 20;

  printf("F    C\n\n");
  fahr = lower;
  while(fahr <= upper)
  {
    celsius = FtoC(fahr);
    printf("%3.0f %6.1f\n", fahr, celsius);
    fahr = fahr + step;
  }
  return 0;
}
```

Answer to Exercise 1-16, page 30

Revise the main routine of the longest-line program so it will correctly print the length of arbitrarily long input lines, and as much as possible of the text.

```
/* This is the first program exercise where the spec isn't entirely
 * clear. The spec says, 'Revise the main routine', but the true
 * length of an input line can only be determined by modifying
 * getline. So that's what we'll do. getline will now return the
 * actual length of the line rather than the number of characters
 * read into the array passed to it.
 */

#include <stdio.h>

#define MAXLINE 1000 /* maximum input line size */

int getline(char line[], int maxline);
void copy(char to[], char from[]);

/* print longest input line */
int main(void)
{
  int len;            /* current line length */
  int max;            /* maximum length seen so far */
  char line[MAXLINE];   /* current input line */
  char longest[MAXLINE]; /* longest line saved here */

  max = 0;

  while((len = getline(line, MAXLINE)) > 0)
  {
    printf("%d: %s", len, line);

    if(len > max)
    {
      max = len;
      copy(longest, line);
    }
  }
  if(max > 0)
  {
    printf("Longest is %d characters:\n%s", max, longest);
  }
  printf("\n");
  return 0;
```

```
}

/* getline: read a line into s, return length */
int getline(char s[], int lim)
{
  int c, i, j;

  for(i = 0, j = 0; (c = getchar())!=EOF && c != '\n'; ++i)
  {
    if(i < lim - 1)
    {
      s[j++] = c;
    }
  }
  if(c == '\n')
  {
    if(i <= lim - 1)
    {
      s[j++] = c;
    }
    ++i;
  }
  s[j] = '\0';
  return i;
}

/* copy: copy 'from' into 'to'; assume 'to' is big enough */
void copy(char to[], char from[])
{
  int i;

  i = 0;
  while((to[i] = from[i]) != '\0')
  {
    ++i;
  }
}
```

Chris Sidi, however, was not convinced - he thought this answer was "too easy", so he checked with bwk, who agreed. Chris writes: "Looks like Mr. Kernighan meant for "main routine" in Exercise 1-16 to refer to function main(), saying your solution of

modifying getline() is "too easy." :) (Though I think your solution shouldn't be removed from the Answers web site, just complimented with another one that only modifies main())"

Cue Mr "386sx", riding to the rescue on a white horse...

```
/* Exercise 1-16 */

#include <stdio.h>

#define MAXLINE 20

int getline(char s[], int lim);
void copy(char to[], char from[]);

int main(void)
{
    char line[MAXLINE];
    char longest[MAXLINE];
    char temp[MAXLINE];
    int len, max, prevmax, getmore;

    max = prevmax = getmore = 0;
    while((len = getline(line, MAXLINE)) > 0)
    {
        if(line[len - 1] != '\n')
        {
            if(getmore == 0)
                copy(temp, line);
            prevmax += len;
            if(max < prevmax)
                max = prevmax;
            getmore = 1;
        }
        else
        {
            if(getmore == 1)
            {
                if(max < prevmax + len)
                {
                    max = prevmax + len;
                    copy(longest, temp);
                    longest[MAXLINE - 2] = '\n';
                }
```

```
            getmore = 0;
        }

        else if(max < len)
        {
            max = len;
            copy(longest, line);
        }
        prevmax = 0;
    }
}
if(max > 0)
{
    printf("%s", longest);
    printf("len = %d\n", max);
}

return 0;
}

int getline(char s[], int lim)
{
int c, i;

for(i = 0;
    i < lim - 1 && ((c = getchar()) != EOF && c != '\n');
    ++i)
    s[i] = c;

if(c == '\n')
{
    s[i] = c;
    ++i;
}
else if(c == EOF && i > 0)
{
    /* gotta do something about no newline preceding EOF */
    s[i] = '\n';
    ++i;
}
s[i] = '\0';
return i;
}
```

```
void copy(char to[], char from[])
{
    int i;

    i = 0;
    while((to[i] = from[i]) != '\0')
        ++i;
}
```

Answer to Exercise 1-17, page 31

Write a program to print all input lines that are longer than 80 characters.

```
#include <stdio.h>

#define MINLENGTH 81

int readbuff(char *buffer) {
    size_t i=0;
    int c;
    while (i < MINLENGTH) {
        c = getchar();
        if (c == EOF) return -1;
        if (c == '\n') return 0;
        buffer[i++] = c;
    }
    return 1;
}

int copyline(char *buffer) {
    size_t i;
    int c;
    int status = 1;
    for(i=0; i<MINLENGTH; i++)
        putchar(buffer[i]);
    while(status == 1) {
        c = getchar();
        if (c == EOF)
            status = -1;
        else if (c == '\n')
            status = 0;
        else
            putchar(c);
    }
```

```
    putchar('\n');
    return status;
}

int main(void) {
    char buffer[MINLENGTH];
    int status = 0;
    while (status != -1) {
        status = readbuff(buffer);
        if (status == 1)
            status = copyline(buffer);
    }
    return 0;
}
```

Answer to Exercise 1-18, page 31

Write a program to remove all trailing blanks and tabs from each line of input, and to delete entirely blank lines.

```
/* K&R2 1-18 p31: Write a program to remove trailing blanks and tabs
   from each line of input, and to delete entirely blank lines.

   The program specification is ambiguous: does "entirely blank lines"
   mean lines that contain no characters other than newline, or does
   it include lines composed of blanks and tabs followed by newline?
   The latter interpretation is taken here.

   This implementation does not use any features not introduced in the
   first chapter of K&R2.  As a result, it can't use pointers to
   dynamically allocate a buffer to store blanks that it has seen, so
   it must limit the number of blanks that are allowed to occur
   consecutively.  (This is the value of MAXQUEUE, minus one.)

   It is intended that this implementation "degrades gracefully."
   Even though a particular input might have 1000 or more blanks or
   tabs in a row, causing a problem for a single pass, multiple passes
   through the file will correct the problem.  The program signals the
   need for such an additional pass by returning a failure code to the
   operating system.  (EXIT_FAILURE isn't mentioned in the first
   chapter of K&R, but I'm making an exception here.) */

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

```c
#define MAXQUEUE 1001

int advance(int pointer)
{
  if (pointer < MAXQUEUE - 1)
    return pointer + 1;
  else
    return 0;
}

int main(void)
{
  char blank[MAXQUEUE];
  int head, tail;
  int nonspace;
  int retval;
  int c;

  retval = nonspace = head = tail = 0;
  while ((c = getchar()) != EOF) {
    if (c == '\n') {
      head = tail = 0;
      if (nonspace)
        putchar('\n');
      nonspace = 0;
    }
    else if (c == ' ' || c == '\t') {
      if (advance(head) == tail) {
        putchar(blank[tail]);
        tail = advance(tail);
        nonspace = 1;
        retval = EXIT_FAILURE;
      }

      blank[head] = c;
      head = advance(head);
    }
    else {
      while (head != tail) {
        putchar(blank[tail]);
        tail = advance(tail);
      }
      putchar(c);
```

```
      nonspace = 1;
    }
  }

  return retval;
}
```

Chris Sidi writes:

Ben,

I thought your solution to 1-18 was really neat (it didn't occur to me when I was doing the exercise), the way it degrades gracefully and multiple passes can get rid of huge blocks of whitespace.

However, if there is a huge block of non-trailing whitespace (eg "A",2000 spaces, "B\n") your program returns an error when there's not a need for it. And if someone were to use your program till it passes it will loop infinitely:

```
  $ perl -e 'print "A"," "x2000,"B\n";' > in
  $ until ./a.out < in > out; do echo failed, running another pass; cp
out
    in; done
  failed, running another pass
  failed, running another pass
  failed, running another pass
  [snip]
```

Below I have added a variable spaceJustPrinted to your program and check to see if the spaces printed early are trailing. I hope you like the minor improvement. (Though I can understand if you don't give a [1] :)) [1] expletive deleted - RJH.

```
/* K&R2 1-18 p31: Write a program to remove trailing blanks and tabs
   from each line of input, and to delete entirely blank lines.

   The program specification is ambiguous: does "entirely blank lines"
   mean lines that contain no characters other than newline, or does
   it include lines composed of blanks and tabs followed by newline?
   The latter interpretation is taken here.
```

```
   This implementation does not use any features not introduced in the
   first chapter of K&R2.  As a result, it can't use pointers to
   dynamically allocate a buffer to store blanks that it has seen, so
   it must limit the number of blanks that are allowed to occur
   consecutively.  (This is the value of MAXQUEUE, minus one.)

   It is intended that this implementation "degrades gracefully."
   Even though a particular input might have 1000 or more trailing
   blanks or tabs in a row, causing a problem for a single pass,
   multiple passes through the file will correct the problem.  The
   program signals the need for such an additional pass by returning a
   failure code to the operating system.  (EXIT_FAILURE isn't mentioned
   in the first chapter of K&R, but I'm making an exception here.) */

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

#define MAXQUEUE 1001

int advance(int pointer)
{
  if (pointer < MAXQUEUE - 1)
    return pointer + 1;
  else
    return 0;
}

int main(void)
{
  char blank[MAXQUEUE];
  int head, tail;
  int nonspace;
  int retval;
  int c;
  int spaceJustPrinted; /*boolean: was the last character printed
whitespace?*/

  retval = spaceJustPrinted = nonspace = head = tail = 0;

  while ((c = getchar()) != EOF) {
    if (c == '\n') {
      head = tail = 0;
```

```
     if (spaceJustPrinted == 1) /*if some trailing whitespace was
printed...*/
       retval = EXIT_FAILURE;

     if (nonspace) {
       putchar('\n');
       spaceJustPrinted = 0; /* this instruction isn't really necessary
since
                             spaceJustPrinted is only used to determine the
                             return value, but we'll keep this boolean
                             truthful */
       nonspace = 0;  /* moved inside conditional just to save a needless
                       assignment */
     }
   }
   else if (c == ' ' || c == '\t') {
     if (advance(head) == tail) {
       putchar(blank[tail]); /* these whitespace chars being printed
early
                             are only a problem if they are trailing,
                             which we'll check when we hit a \n or EOF */
       spaceJustPrinted = 1;
       tail = advance(tail);
       nonspace = 1;
     }

     blank[head] = c;
     head = advance(head);
   }
   else {
     while (head != tail) {
       putchar(blank[tail]);
       tail = advance(tail);
     }
     putchar(c);
     spaceJustPrinted = 0;
     nonspace = 1;
   }
 }

 /* if the last line wasn't ended with a newline before the EOF,
 we'll need to figure out if trailing space was printed here */
 if (spaceJustPrinted == 1) /*if some trailing whitespace was
printed...*/
```

```
    retval = EXIT_FAILURE;

  return retval;
}
```

Answer to Exercise 1-19, page 31

Write a function `reverse(s)` that reverses the character string `s` . Use it to write a program that reverses its input a line at a time.

```
#include <stdio.h>

#define MAX_LINE 1024

void discardnewline(char s[])
{
  int i;
  for(i = 0; s[i] != '\0'; i++)
  {
    if(s[i] == '\n')
      s[i] = '\0';
  }
}

int reverse(char s[])
{
  char ch;
  int i, j;

  for(j = 0; s[j] != '\0'; j++)
  {
  }

  --j;

  for(i = 0; i < j; i++)
  {
    ch   = s[i];
    s[i] = s[j];
    s[j] = ch;
    --j;
  }

  return 0;
```

```
}

int getline(char s[], int lim)
{
  int c, i;

  for(i = 0; i < lim - 1 && (c = getchar()) != EOF && c != '\n'; ++i)
  {
    s[i] = c;
  }

  if(c == '\n')
  {
    s[i++] = c;
  }

  s[i] = '\0';

  return i;

}

int main(void)
{
  char line[MAX_LINE];

  while(getline(line, sizeof line) > 0)
  {
    discardnewline(line);
    reverse(line);
    printf("%s\n", line);
  }
  return 0;
}
```

Answer to Exercise 1-20, page 34

Thanks to Rick Dearman for pointing out that my solution used `fgets()` which has not been introduced by page 34. I've fixed the solution to use K&R's getline() function instead. Further thanks to Roman Yablonovsky who, in Oct 2000, pointed out that the solution was buggy, and hinted at a fix. Basically, the problem he spotted was that my solution failed to keep track of the cumulative effect of multiple tabs in a single line. I've adopted his fix (which was in fact also slightly buggy, but I've fixed that too).

Write a program `detab` that replaces tabs in the input with the proper number of blanks to space to the next tab stop. Assume a fixed set of tab stops, say every n *columns. Should* n *be a variable or a symbolic parameter?*

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

#define MAX_BUFFER   1024
#define SPACE        ' '
#define TAB          '\t'

int CalculateNumberOfSpaces(int Offset, int TabSize)
{
   return TabSize - (Offset % TabSize);
}

/* K&R's getline() function from p29 */
int getline(char s[], int lim)
{
  int c, i;

  for(i = 0; i < lim - 1 && (c = getchar()) != EOF && c != '\n'; ++i)
    s[i] = c;
  if(c == '\n')
  {
    s[i] = c;
    ++i;
  }
  s[i] = '\0';

  return i;
}

int main(void)
{
  char  Buffer[MAX_BUFFER];
  int TabSize = 5; /* A good test value */

  int i, j, k, l;

  while(getline(Buffer, MAX_BUFFER) > 0)
  {
```

```
    for(i = 0, l = 0; Buffer[i] != '\0'; i++)
    {
      if(Buffer[i] == TAB)
      {
        j = CalculateNumberOfSpaces(l, TabSize);
        for(k = 0; k < j; k++)
        {
          putchar(SPACE);
          l++;
        }
      }
      else
      {
        putchar(Buffer[i]);
        l++;
      }
    }
  }

  return 0;
}
```

In answer to the question about whether *n* should be variable or symbolic, I'm tempted to offer the answer 'yes'. :-) Of course, it should be variable, to allow for modification of the value at runtime, for example via a command line argument, without requiring recompilation.

Answer to Exercise 1-21, page 34

Write a program `entab` that replaces strings of blanks with the minimum number of tabs and blanks to achieve the same spacing. Use the same stops as for `detab` . When either a tab or a single blank would suffice to reach a tab stop, which should be given preference?

Rick Dearman's Cat 0 solution:

```
/*****************************************************
   KnR 1-21
   --------
```

```
   Write a program "entab" which replaces strings of
   blanks with the minimum number of tabs and blanks
   to achieve the same spacing.

   Author: Rick Dearman
   email: rick@ricken.demon.co.uk

*****************************************************/
#include <stdio.h>

#define MAXLINE 1000 /* max input line size */
#define TAB2SPACE 4 /* 4 spaces to a tab */

char line[MAXLINE]; /*current input line*/

int getline(void);  /* taken from the KnR book. */


int
main()
{
  int i,t;
  int spacecount,len;

  while (( len = getline()) > 0 )
    {
      spacecount = 0;
      for( i=0; i < len; i++)
         {
          if(line[i] == ' ')
            spacecount++; /* increment counter for each space */
          if(line[i] != ' ')
            spacecount = 0; /* reset counter */
          if(spacecount == TAB2SPACE) /* Now we have enough spaces
                                      ** to replace them with a tab
                                      */
           {
             /* Because we are removing 4 spaces and
             ** replacing them with 1 tab we move back
             ** three chars and replace the ' ' with a \t
             */
             i -= 3; /* same as "i = i - 3" */
             len -= 3;
             line[i] = '\t';
```

```
            /* Now move all the char's to the right into the
            ** places we have removed.
            */
            for(t=i+1;t<len;t++)
               line[t]=line[t+3];
            /* Now set the counter back to zero and move the
            ** end of line back 3 spaces
            */
            spacecount = 0;
            line[len] = '\0';
          }
        }
      printf("%s", line);
    }
  return 0;
}


/* getline: specialized version */
int getline(void)
{
  int c, i;
  extern char line[];

  for ( i=0;i<MAXLINE-1 && ( c=getchar()) != EOF && c != '\n'; ++i)
    line[i] = c;
  if(c == '\n')
    {
      line[i] = c;
      ++i;
    }
  line[i] = '\0';
  return i;

}
```

Stefan Farfeleder's Cat 1 solution:

```
/* 1-21.c */

#include <stdio.h>
```

```c
#define TABSTOP 4

int main(void)
{
    size_t spaces = 0;
    int ch;
    size_t x = 0;             /* position in the line */
    size_t tabstop = TABSTOP;   /* get this from the command-line
                                 * if you want to */

    while ((ch = getchar()) != EOF)
    {
        if (ch == ' ')
        {
            spaces++;
        }
        else if (spaces == 0) /* no space, just printing */
        {
            putchar(ch);
            x++;
        }
        else if (spaces == 1) /* just one space, never print a tab */
        {
            putchar(' ');
            putchar(ch);
            x += 2;
            spaces = 0;
        }
        else
        {
            while (x / tabstop != (x + spaces) / tabstop)
                /* are the spaces reaching behind the next tabstop ? */
            {
                putchar('\t');
                x++;
                spaces--;
                while (x % tabstop != 0)
                {
                    x++;
                    spaces--;
                }
            }

            while (spaces > 0) /* the remaining ones are real space */
```

```
            {
                putchar(' ');
                x++;
                spaces--;
            }
            putchar(ch); /* now print the non-space char */
            x++;
        }
        if (ch == '\n')
        {
            x = 0; /* reset line position */
        }
    }

    return 0;
}
```

Answer to Exercise 1-22, page 34

Write a program to "fold" long input lines into two or more shorter lines after the last non-blank character that occurs before the n -th column of input. Make sure your program does something intelligent with very long lines, and if there are no blanks or tabs before the specified column.

Category 1 Solution

```
/*******************************************************
   KnR 1-22
   --------
   Write a program that wraps very long lines of input
   into two or more shorter lines.

   Author: Rick Dearman
   email: rick@ricken.demon.co.uk

*******************************************************/
#include <stdio.h>

#define MAXLINE 1000 /* max input line size */
```

```c
char line[MAXLINE]; /*current input line*/

int getline(void);  /* taken from the KnR book. */


int
main()
{
  int t,len;
  int location,spaceholder;
  const int FOLDLENGTH=70; /* The max length of a line */

  while (( len = getline()) > 0 )
    {
      if( len < FOLDLENGTH )
         {
         }
      else
         {
         /* if this is an extra long line then we
         ** loop through it replacing a space nearest
         ** to the foldarea with a newline.
         */
           t = 0;
           location = 0;
           while(t<len)
             {
               if(line[t] == ' ')
                  spaceholder = t;

               if(location==FOLDLENGTH)
                  {
                    line[spaceholder] = '\n';
                    location = 0;
                  }
               location++;
               t++;
             }
         }
      printf ( "%s", line);
    }
  return 0;
}
```

```
/* getline: specialized version */
int getline(void)
{
  int c, i;
  extern char line[];

  for ( i=0;i<MAXLINE-1 && ( c=getchar()) != EOF && c != '\n'; ++i)
    line[i] = c;
  if(c == '\n')
    {
      line[i] = c;
      ++i;
    }
  line[i] = '\0';
  return i;

}
```

Answer to Exercise 1-23, page 34

Write a program to remove all comments from a C program. Don't forget to handle quoted strings and character constants properly. C comments do not nest.

This was the first exercise to be posted as a fun "competition" on comp.lang.c, on 1 June 2000. As a result, there was a small flurry of submissions. Not all of them are completely working solutions. See the very end of this page for a test program which breaks most of them. :-)

Category 0 Solutions

From Rick Dearman

Now handles "/* comment in string */" correctly, but does not remove the comment from

```
  return /* comment inside return statement */ 0;
```

```
/*******************************************************
"Write a program to remove all comments from a C program.
Don't forget to handle quoted strings and character
constants properly. C comments do not nest."

Author: Rick Dearman (rick@ricken.demon.co.uk)
*******************************************************/

#include <stdio.h>

#define MAXLINE 1000 /* max input line size */
char line[MAXLINE]; /*current input line*/

int getline(void);  /* taken from the KnR book. */


int
main()
{
  int in_comment,len;
  int in_quote;
  int t;

  in_comment = in_quote = t = 0;
  while ((len = getline()) > 0 )
    {
      t=0;
      while(t < len)
        {
           if( line[t] == '"')
                 in_quote = 1;

           if( ! in_quote )
           {
                 if( line[t] == '/' && line[t+1] == '*')
                 {
                        t=t+2;
                        in_comment = 1;
                 }
                 if( line[t] == '*' && line[t+1] == '/')
                 {
                        t=t+2;
                        in_comment = 0;
```

```
                }
                if(in_comment == 1)
                 {
                        t++;
                }
                else
                {
                        printf ("%c", line[t]);
                        t++;
                }
          }
          else
          {
            printf ("%c", line[t]);
            t++;
          }
        }
    }
  return 0;
}


/* getline: specialized version */
int getline(void)
{
  int c, i;
  extern char line[];

  for ( i=0;i<MAXLINE-1 && ( c=getchar()) != EOF && c != '\n'; ++i)
    line[i] = c;
  if(c == '\n')
    {
      line[i] = c;
      ++i;
    }
  line[i] = '\0';
  return i;

}
```

From Ben Pfaff

This version is a bugfix for the code var/'\2'

```
/* K&R2 1-23: Write a program to remove all comments from a C program.
   Don't forget to handle quoted strings and character constants
   properly.  C comments do not nest.

   This solution does not deal with other special cases, such as
   trigraphs, line continuation with \, or <> quoting on #include,
   since these aren't mentioned up 'til then in K&R2.  Perhaps this is
   cheating.

   Note that this program contains both comments and quoted strings of
   text that looks like comments, so running it on itself is a
   reasonable test.  It also contains examples of a comment that ends
   in a star and a comment preceded by a slash.  Note that the latter
   will break C99 compilers and C89 compilers with // comment
   extensions.

   Interface: The C source file is read from stdin and the
   comment-less output is written to stdout. **/

#include <stdio.h>

int
main(void)
{
#define PROGRAM 0
#define SLASH 1
#define COMMENT 2
#define STAR 3
#define QUOTE 4
#define LITERAL 5

    /* State machine's current state, one of the above values. */
    int state;

    /* If state == QUOTE, then ' or ".  Otherwise, undefined. */
    int quote;

    /* Input character. */
    int c;

    state = PROGRAM;
```

```
while ((c = getchar()) != EOF) {
    /* The following cases are in guesstimated order from most common
       to least common. */
    if (state == PROGRAM || state == SLASH) {
        if (state == SLASH) {
            /* Program text following a slash. */
            if (c == '*')
                state = COMMENT;
            else {
                putchar('/');
                state = PROGRAM;
            }
        }

        if (state == PROGRAM) {
            /* Program text. */
            if (c == '\'' || c == '"') {
                quote = c;
                state = QUOTE;
                putchar(c);
            }
            else if (c == "/*"[0])
                state = SLASH;
            else
                putchar(c);
        }
    }
    else if (state == COMMENT) {
        /* Comment. */
        if (c == "/*"[1])
            state = STAR;
    }
    else if (state == QUOTE) {
        /* Within quoted string or character constant. */
        putchar(c);
        if (c == '\\')
            state = LITERAL;
        else if (c == quote)
            state = PROGRAM;
    }
    else if (state == SLASH) {
    }
    else if (state == STAR) {
        /* Comment following a star. */
```

```
            if (c == '/')
                state = PROGRAM;
            else if (c != '*')
                state = COMMENT;
        }
        else /* state == LITERAL */ {
            /* Within quoted string or character constant, following \. */
            putchar(c);
            state = QUOTE;
        }
    }

    if (state == SLASH)
        putchar('/' //**/
              1);

    return 0;
}

/*
   Local variables:
   compile-command: "checkergcc -W -Wall -ansi -pedantic knr123-0.c -o
knr123-0"
   End:
*/
```

From Lew Pitcher

```
/* Lew Pitcher <lpitcher@yesic.com> */

/*/
** derem - remove C comments
**
** (attempt to solve K&R Exercise 1-22)
**
** As I only have v1 copy of K&R, I cannot
** be sure what is covered in K&R ANSI chapter 1.
** So, I restrict myself to the components covered
** in K&R v1 chapter 1, but modified for requisite ANSI
```

```
** features (int main() and return value).
**
** Components covered in v1 K&R chapter 1 include:
**  while (), for (), if () else
**  getchar(), putchar(), EOF
**  character constants, character escapes
**  strings
**  array subscripting
**
** Not directly covered are
**  string subscripting ( "/*"[0] )
**  initializers ( int state = PROGRAM; )
**/

/*/*/

#include <stdio.h>

#define PROGRAM         0
#define BEGIN_COMMENT   1
#define COMMENT         2
#define END_COMMENT     3
#define QUOTE           4

int main(void)
{
        int this_char, quote_char;
        int state;

        state = PROGRAM;

        while ((this_char = getchar()) != EOF)
        {
                if (state == PROGRAM)
                {
                        if (this_char == '/')
                                state = BEGIN_COMMENT;
                        else if ((this_char == '"') || (this_char ==
'\''))
                        {
                                state = QUOTE;
                                putchar(quote_char = this_char);
                        }
                        else    putchar(this_char);
```

```
                }
                else if (state == BEGIN_COMMENT)
                {
                        if (this_char == '*')
                                state = COMMENT;
                        else
                        {
                                putchar('/'); /* for the '/' of the
comment */
                                if (this_char != '/')
                                {
                                        state = PROGRAM;
                                        putchar(this_char);
                                }
                                else    state = COMMENT;       /*
stuttered */
                        }
                }
                else if (state == QUOTE)
                {
                        putchar(this_char);
                        if (this_char == '\\')
                                putchar(getchar());    /* escaped
character */
                        else if (this_char == quote_char)
                                state = PROGRAM;
                }
                else if (state == COMMENT)
                {
                        if (this_char == '*')
                                state = END_COMMENT;
                }
                else if (state == END_COMMENT)
                {
                        if (this_char == '/')
                                state = PROGRAM;
                        else if (this_char != '*')    /* stuttered */
                                state = COMMENT;
                }
        }

        return 0;
}
```

From Gregory Pietsch

```
/* Gregory Pietsch <gkp1@flash.net> */

#include <stdio.h>

char p[] =
"0/!10\"040\'050.001/011*!21\"/41\'/51./02*!32.!23/ "
"03*!33.!24\"004\\064.045\'005\\075.056.047.05";

int main(){int c,i,d;char s,n;s='0';while((c=getchar())
!=EOF){d=0;for(i=0;p[i]!='\0'&&d==0;i=i+4){if(p[i]==s&&
(p[i+1]==c||p[i+1]=='.')){if(p[i+2]=='0')putchar(c);else
if(p[i+2]=='/'){putchar('/');putchar(c);}else if(p[i+2]
==' ')putchar(' ');n=p[i+3];d=1;}}s=n;}return 0;}
```

Category 1 Solutions

From Ben Pfaff (again)

This version has the var/'\2' bug fix.

```
/* K&R2 1-23: Write a program to remove all comments from a C program.
   Don't forget to handle quoted strings and character constants
   properly.  C comments do not nest.

   This solution does not deal with other special cases, such as
   trigraphs, line continuation with \, or <> quoting on #include,
   since these aren't mentioned up 'til then in K&R2.  Perhaps this is
   cheating.

   Note that this program contains both comments and quoted strings of
   text that looks like comments, so running it on itself is a
   reasonable test.  It also contains examples of a comment that ends
```

```
   in a star and a comment preceded by a slash.  Note that the latter
   will break C99 compilers and C89 compilers with // comment
   extensions.

   Interface: The C source file is read from stdin and the
   comment-less output is written to stdout. **/

#include <stdio.h>

int
main(void)
{
    /* State machine's current state. */
    enum {
        PROGRAM,
        SLASH,
        COMMENT,
        STAR,
        QUOTE,
        LITERAL
    } state;

    /* If state == QUOTE, then ' or ".  Otherwise, undefined. */
    int quote;

    state = PROGRAM;
    for (;;) {
        int c = getchar();
        if (c == EOF) {
            if (state == SLASH)
                putchar('/' //**/
                       1 / 1 /'\1');
            break;
        }

        switch (state) {
        case SLASH:
            /* Program text following a slash. */
            if (c == "/*"[1]) {
                state = COMMENT;
                break;
            }
            putchar('/');
            state = PROGRAM;
```

```
    /* Fall through. */

case PROGRAM:
    /* Program text. */
    if (c == '\'' || c == '"') {
        quote = c;
        state = QUOTE;
        putchar(c);
    }
    else if (c == "/*"[0])
        state = SLASH;
    else
        putchar(c);
    break;

case COMMENT:
    /* Comment. */
    if (c == '*')
        state = STAR;
    break;

case STAR:
    /* Comment following a star. */
    if (c == '/')
        state = PROGRAM;
    else if (c != '*') {
        state = COMMENT;
        putchar (' ');
    }
    break;

case QUOTE:
    /* Within quoted string or character constant. */
    putchar(c);
    if (c == '\\')
        state = LITERAL;
    else if (c == quote)
        state = PROGRAM;
    break;

case LITERAL:
    /* Within quoted string or character constant, following \. */
    putchar(c);
    state = QUOTE;
```

```
            break;

        default:
            abort();
        }
    }

    return 0;
}

/*
   Local variables:
   compile-command: "checkergcc -W -Wall -ansi -pedantic knr123.c -o
knr123"
   End:
*/
```

From Chris Torek

```
/* torek@elf.bsdi.com (Chris Torek) */

/*
"Write a program to remove all comments from a C program. Don't forget
to handle quoted strings and character constants properly. C comments do
not nest."

Well, what the heck.  I mailed this a day or two ago, but here is
the posted version.  I modified the problem a bit: it removes
comments from full ANSI C89 or C99 programs, handling trigraphs
and \-newline sequences.  It attempts to preserve any trigraphs in
the output, even while examining them in the "C code" as their
translated characters.  (I am not sure why I bothered doing all of
them, when only ??/ matters here.)  It keeps output line numbers in
sync with input line numbers, so that if the output is compiled,
any error messages will refer back to the proper input source line.

Lightly tested.
*/

#include <assert.h>
```

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

/*
 * This flag controls whether we do trigraph processing.
 */
int     trigraphs = 1;

/*
 * This flag controls whether a comment becomes "whitespace" (ANSI C)
 * or "nothing at all" (some pre-ANSI K&R C compilers).
 */
int     whitespace = 1;

/*
 * This flag controls whether we do C89 or C99.  (C99 also handles C++.)
 */
int     c99;

/*
 * These are global so that options() can get at them, and for later
 * error messages if needed.
 */
const char *inname, *outname;

int options(const char *, char **);
void usage(void);

void    process(FILE *, FILE *);

#ifdef __GNUC__
void    panic(const char *) __attribute__((noreturn));
#else
void    panic(const char *);
#endif

int main(int argc, char **argv) {
        int i;
        FILE *in, *out;

        for (i = 1; i < argc; i++) {
                if (argv[i][0] == '-')
                        i += options(argv[i] + 1, argv + i + 1);
```

```
                else if (inname == NULL)
                        inname = argv[i];
                else
                        usage();
        }
        if (inname != NULL) {
                if ((in = fopen(inname, "r")) == NULL) {
                        fprintf(stderr, "cannot open %s for reading\n",
inname);
                        exit(EXIT_FAILURE);
                }
        } else {
                inname = "stdin";
                in = stdin;
        }
        if (outname != NULL) {
                if ((out = fopen(outname, "w")) == NULL) {
                        fprintf(stderr, "cannot open %s for writing\n",
                           outname);
                        exit(EXIT_FAILURE);
                }
        } else {
                outname = "stdout";
                out = stdout;
        }
        process(in, out);
        fclose(in);
        fclose(out);
        exit(EXIT_SUCCESS);
}

/*
 * This scans for -o type options.  Options that have an argument
 * can either take it immediately or as a subsequent argument (e.g.,
 * -ofoo means the same thing as -o foo).  We return 0 for "handled
 * them normally", 1 for "handled them normally but needed more
 * arguments".
 *
 * Currently this function is more powerful than really needed, but
 * if we ever decide to have more arguments...
 */
int options(const char *afterdash, char **moreargs) {
        int nmore = 0, c;
```

```
        while ((c = *afterdash++) != '\0') {
                if (c == 'o') {
                        if (*afterdash) {
                                outname = afterdash;
                                afterdash = "";
                        } else if (moreargs[nmore] != NULL)
                                outname = moreargs[nmore++];
                        else
                                usage();
                } else if (c == 't')
                        trigraphs = 0;
                else if (c == 'w')
                        whitespace = 0;
                else if (c == '9')
                        c99 = 1;
                else
                        usage();
        }
        return nmore;
}

void usage(void) {
        fprintf(stderr, "usage: uncomment [-9tw] [-o outfile]
[infile]\n");
        exit(EXIT_FAILURE);    /* ??? */
}

/*
 * States, level 0:
 *      normal
 *      trigraph processing: Q1 Q2 (for ??x)
 *
 * States, level 1:
 *      backslash-newline processing: BACK (seen \, may consume NL)
 *
 * States, level 2:
 *      normal
 *      character constant: CC (seen '), CCBACK (seen \ inside CC)
 *      string constant: SC, SCBACK
 *      comment: SLASH, COMM, COMMSTAR (for /, in-comment, & seen-star)
 *      C99: SLASHSLASH
 */

enum l0state {
```

```
        L0_NORMAL,
        L0_Q1, L0_Q2
};
enum l1state {
        L1_NORMAL,
        L1_BACK
};
enum l2state {
        L2_NORMAL,
        L2_CC, L2_CCBACK,
        L2_SC, L2_SCBACK,
        L2_SLASH, L2_COMM, L2_COMMSTAR,
        L2_SLASHSLASH
};

struct state {
        FILE *in;
        enum l0state l0state;
        int npushback;
        char pushback[4];
        char pushorig[4];      /* nonzero => trigraph pushback */
        int lastgetc;
        int lineno;
};

/*
 * Set up "initial" state.
 */
static void state0(struct state *sp, FILE *in) {
        sp->in = in;
        sp->l0state = L0_NORMAL;
        sp->npushback = 0;
        sp->lastgetc = 0;
        sp->lineno = 1;
}

static void pushback(struct state *sp, int c, char origc) {
        assert(sp->npushback < sizeof sp->pushback);
        sp->pushback[sp->npushback] = c;
        sp->pushorig[sp->npushback++] = origc;
}

/*
 * Get a character, doing trigraph processing.  Set *origc to 0 for normal
```

```
 * characters, or the actual input character pre-trigraph-mapping
 * for trigraph input.
 *
 * As a side effect, this can wind up getting up to 3 characters, maybe
 * stuffing two of them into the pushback buffer sp->buf[].  It also bumps
 * sp->lineno when a previously-read newline has been passed over.
 */
static int getl0char(struct state *sp, char *origc) {
        int c, newc;
        enum l0state state;

        state = sp->l0state;
        *origc = 0;
        while ((c = getc(sp->in)) != EOF) {
                if (sp->lastgetc == '\n')
                        sp->lineno++;
                sp->lastgetc = c;
                switch (state) {

                case L0_NORMAL:
                        /* ? => get another character; otherwise we are
ok */
                        if (c == '?') {
                                state = L0_Q1;
                                continue;
                        }
                        assert(sp->l0state == L0_NORMAL);
                        return c;

                case L0_Q1:
                        /* ?? => get another character */
                        if (c == '?') {
                                state = L0_Q2;
                                continue;
                        }
                        /* ?X => return ?, look at X later */
                        pushback(sp, c, 0);
                        sp->l0state = L0_NORMAL;
                        return '?';

                case L0_Q2:
                        /*
                         * ??X, where X is trigraph => map
                         * ??X, where X is non-trigraph => tricky
```

```
                         * ??? => also tricky
                         */
                        switch (c) {
                        case '=':
                                newc = '#';
                                break;
                        case '(':
                                newc = '[';
                                break;
                        case '/':
                                newc = '\\';
                                break;
                        case ')':
                                newc = ']';
                                break;
                        case '\'':
                                newc = '^';
                                break;
                        case '<':
                                newc = '{';
                                break;
                        case '!':
                                newc = '|';
                                break;
                        case '>':
                                newc = '}';
                                break;
                        case '?':
                                /*
                                 * This one is slightly tricky.  Three
'?'s
                                 * mean that the '?' we read two characters
                                 * ago gets returned, and the two
remaining
                                 * '?'s leave us in Q2 state.
                                 */
                                sp->l0state = L0_Q2;
                                return '?';
                        default:
                                /*
                                 * This one returns the first ?, leaves
                                 * the second ? to be re-examined, and
                                 * leaves the last character to be
re-examined.
```

```
                                 * In any case we are back in "normal"
state.
                                 */
                                pushback(sp, c, 0);
                                pushback(sp, '?', 0);
                                sp->l0state = L0_NORMAL;
                                return '?';
                        }
                        /* mapped a trigraph char -- return new char */
                        *origc = c;
                        sp->l0state = L0_NORMAL;
                        return newc;

                default:
                        panic("getl0char state");
                }
        }
        sp->lastgetc = EOF;
        return EOF;
}

void warn(struct state *, const char *);

void process(FILE *in, FILE *out) {
        enum l1state l1state = L1_NORMAL;
        enum l2state l2state = L2_NORMAL;
        int c, pendnls;
        char origc, backc;
        struct state state;

        state0(&state, in);
        pendnls = 0;
        backc = 0;              /* defeat gcc warning */

        /*
         * Slight sort-of-bug: files ending in \ cause two "final" getc()s.
         */
        do {
                if (state.npushback) {
                        c = state.pushback[--state.npushback];
                        origc = state.pushorig[state.npushback];
                } else if (trigraphs) {
                        c = getl0char(&state, &origc);
                } else {
```

```
        c = getc(in);
        origc = 0;
        if (state.lastgetc == '\n')
                state.lineno++;
        state.lastgetc = c;
}

/*
 * Do backslash-newline processing.
 */
switch (l1state) {

case L1_NORMAL:
        if (c == '\\') {
                l1state = L1_BACK;
                backc = origc;
                continue;
        }
        break;

case L1_BACK:
        /*
         * If backc is nonzero here, the backslash that
         * got us into this state was spelled ??/ --
         * if we eat a newline (and hence the backslash),
         * we forget that the eaten newline was spelled
         * this way.  This is sort of a bug, but so it goes.
         */
        l1state = L1_NORMAL;
        if (c == '\n') {
                pendnls++;
                continue;
        }
        if (c != EOF)
                pushback(&state, c, origc);
        c = '\\';
        origc = backc;
        break;

default:
        panic("bad l1state");
}

/*
```

```
                 * Now ready to do "C proper" processing.
                 */
#define SYNCLINES()     while (pendnls) putc('\n', out), pendnls--
#define OUTPUT(ch, tri) ((tri) ? fprintf(out, "??%c", tri) : putc(ch,
out))
#define COPY()          OUTPUT(c, origc)

                switch (l2state) {
                case L2_NORMAL:
                        switch (c) {
                        case '\'':
                                l2state = L2_CC;
                                break;
                        case '"':
                                l2state = L2_SC;
                                break;
                        case '/':
                                l2state = L2_SLASH;
                                continue;
                        default:
                                break;
                        }
                        SYNCLINES();
                        if (c != EOF)
                                COPY();
                        break;

                case L2_CC:
                        switch (c) {
                        case EOF:
                                warn(&state, "EOF in character
constant");
                                break;
                        case '\n':
                                warn(&state, "newline in character
constant");
                                break;
                        case '\\':
                                l2state = L2_CCBACK;
                                break;
                        case '\'':
                                l2state = L2_NORMAL;
                                break;
                        default:
```

```
                        break;
                }
                if (c != EOF)
                        COPY();
                break;

        case L2_CCBACK:
                switch (c) {
                case EOF:
                        warn(&state, "EOF in character
constant");
                        break;
                case '\n':
                        warn(&state, "newline in character
constant");
                        break;
                default:
                        break;
                }
                l2state = L2_CC;
                if (c != EOF)
                        COPY();
                break;

        case L2_SC:     /* much like CC */
                switch (c) {
                case EOF:
                        warn(&state, "EOF in string constant");
                        break;
                case '\n':
                        warn(&state, "newline in string
constant");
                        break;
                case '\\':
                        l2state = L2_SCBACK;
                        break;
                case '"':
                        l2state = L2_NORMAL;
                        break;
                default:
                        break;
                }
                if (c != EOF)
                        COPY();
```

```
                        break;

                case L2_SCBACK:
                        switch (c) {
                        case EOF:
                                warn(&state, "EOF in string constant");
                                break;
                        case '\n':
                                warn(&state, "newline in string
constant");
                                break;
                        default:
                                break;
                        }
                        l2state = L2_SC;
                        if (c != EOF)
                                COPY();
                        break;

                case L2_SLASH:
                        if (c == '*')
                                l2state = L2_COMM;
                        else if (c99 && c == '/')
                                l2state = L2_SLASHSLASH;
                        else {
                                SYNCLINES();
                                OUTPUT('/', 0);
                                if (c != '/') {
                                        if (c != EOF)
                                                COPY();
                                        l2state = L2_NORMAL;
                                }
                        }
                        break;

                case L2_COMM:
                        switch (c) {
                        case '*':
                                l2state = L2_COMMSTAR;
                                break;
                        case '\n':
                                pendnls++;
                                break;
                        case EOF:
```

```
                        warn(&state, "EOF inside comment");
                        break;
                }
                break;

        case L2_COMMSTAR:
                switch (c) {
                case '/':
                        l2state = L2_NORMAL;
                        /*
                         * If comments become whitespace,
                         * and we have no pending newlines,
                         * must emit a blank here.
                         *
                         * The comment text is now all eaten.
                         */
                        if (whitespace && pendnls == 0)
                                putc(' ', out);
                        SYNCLINES();
                        break;
                case '*':
                        /* stay in L2_COMMSTAR state */
                        break;
                case EOF:
                        warn(&state, "EOF inside comment");
                        break;
                case '\n':
                        pendnls++;
                        /* FALLTHROUGH */
                default:
                        l2state = L2_COMM;
                }
                break;

        case L2_SLASHSLASH:
                switch (c) {
                case EOF:
                        /* ??? do we really care? */
                        warn(&state, "EOF inside //-comment");
                        break;
                case '\n':
                        l2state = L2_NORMAL;
                        pendnls++;      /* cheesy, but... */
                        SYNCLINES();
```

```
                        default:
                                break;
                        }
                        break;

                default:
                        panic("bad l2state");
                }
        } while (c != EOF);
        SYNCLINES();
}

void warn(struct state *sp, const char *msg) {
        fprintf(stderr, "uncomment: %s(%d): %s\n", inname, sp->lineno,
msg);
}

void panic(const char *msg) {
        fprintf(stderr, "panic: %s\n", msg);
        abort();
        exit(EXIT_FAILURE);
}
```

From Chris Mears

Here's Chris's updated version, without the bugs (says he). **:-)**

```
/*
 * C comment stripper.
 *
 * Strips comments from C or C++ code.
 */

#include <stdio.h>

enum state_t { normal, string, character, block_comment, line_comment};

enum token_t { none, backslash, slash, star, tri1, tri2, tri_backslash};

static int print_mode(enum state_t s)
{
       return (s == normal || s == string || s == character);
```

```
}

void cstrip(FILE *infile, FILE *outfile)
{
	int ch;
	int comment_newline = 0;
	enum state_t state = normal;
	enum token_t token = none;
	enum token_t last_token = none;

	if (!infile || !outfile || (infile == outfile)) {
		return;
	}


	while ((ch = fgetc(infile)) != EOF) {
		switch (ch) {
		case '/':
			if (token == tri2) {
				token = tri_backslash;
				if (print_mode(state))
					fputc(ch, outfile);
			} else if (state == string || state == character) {
				fputc(ch, outfile);
				token = slash;
			} else if (state == block_comment && token == star)
{
				state = normal;
				token = none;

				/* Replace block comments with whitespace. */
				if (comment_newline) {
					fputc('\n', outfile);
				} else {
					fputc(' ', outfile);
				}
			} else if (state == normal && token == slash) {
				state = line_comment;
				token = slash;
			} else {
				token = slash;
			}

			break;
```

```
case '\\':
	if (state == normal && token == slash)
		fputc('/', outfile);
	if (print_mode(state))
		fputc(ch, outfile);

	if (token == backslash || token == tri_backslash) {
		token = none;
	} else {
		last_token = token;
		token = backslash;
	}

	break;

case '"':
	if (state == normal && token == slash)
		fputc('/', outfile);
	if (state == string && token != backslash)
		state = normal;
	else if (state == normal && token != backslash)
		state = string;

	if (print_mode(state))
		fputc(ch, outfile);

	token = none;

	break;

case '\'':
	if (state == normal && token == slash)
		fputc('/', outfile);
	if (state == character && token != backslash)
		state = normal;
	else if (state == normal && token != backslash)
		state = character;

	if (print_mode(state))
		fputc(ch, outfile);

	token = none;
```

```
        break;

    case '\n':
        /* This test is independent of the others. */
        if (state == block_comment)
            comment_newline = 1;

        if (state == normal && token == slash)
            fputc('/', outfile);

        if (token == backslash || token == tri_backslash)
            token = last_token;
        else if (state == line_comment &&
                 token != backslash) {
            state = normal;
            token = none;
        } else {
            token = none;
        }

        if (print_mode(state))
            fputc(ch, outfile);

        break;

    case '*':
        if (state == normal && token == slash) {
            state = block_comment;
            token = none;
            comment_newline = 0;
        } else {
            token = star;
        }

        if (print_mode(state))
            fputc(ch, outfile);

        break;

    case '?':
        if (state == normal && token == slash)
            fputc('/', outfile);

        if (token == tri1) {
```

```
                        token = tri2;
                } else if (token == tri2) {
                        token = tri2;   /* retain state */
                } else {
                        /* We might need the last token if this
                         * trigraph turns out to be a backslash.
                         */
                        last_token = token;
                        token = tri1;
                }

                if (print_mode(state))
                        fputc(ch, outfile);

                break;

        default:
                if (state == normal && token == slash)
                        fputc('/', outfile);

                if (print_mode(state))
                        fputc(ch, outfile);

                token = none;

                break;
        } /* switch */

    } /* while */

    return;
}


/* Small driver program. */

int main(void)
{
    cstrip(stdin, stdout);

    return 0;
}
```

Here's a critique of the above, sent in by Rick Litherland. (Please note: when Rick posted this, I hadn't yet posted Chris Mears's updated version of the code.)

(Since I find it hard to pick the solution number out of KRX12300.C at a glance, I'll refer to the solutions as uncomment00, uncomment01, and so on.)

[Rick - KR means K&R. X means eXercise. 1 means Chapter 1. 23 means exercise 23. The next digit is the category number - 0 == Cat 0 (ANSI C89, with code restricted to what K&R have discussed at this point in the book). The final digit is the solution number. 0 is the first I received in that category, 1 is the second, and so on. (RJH)]

uncomment03 (Gregory Pietsch)

==========

I can find only one possible flaw in this, namely that it does not allow for a slash in program text being immediately followed by a quotation mark. One could reasonably argue that this is not a flaw at all, because that would never happen in sensible code. On the other hand, it can happen in legal code, as demonstrated by the following complete (if useless) program.

```
#include <stdio.h>
int main(void)
{
    /* print the number three */
    printf("%d\n", 6/'\2');
    /* remember to return a value from main */
    return 0;
}
```

When this is fed to uncomment03, the output is

```
#include <stdio.h>
int main(void)
{

    printf("%d\n", 6/'\2');
    /* remember to return a value from main */
```

```
    return 0;
}
```

Clearly, uncomment03 realises that the second comment is too important to remove. Um, sorry, that was a feeble excuse for a joke. What's happening is that uncomment03 doesn't recognise the beginning of the character constant '\2', so it takes the closing quote as the start of a "character constant" that is never terminated. The peculiar idiom 6/'\2' for 3 can be replaced by the even more brain-damaged 6/"\2"[0] with the same effect. Since uncomment03 is table-driven, it's easy to make it recognise these situations by adding two new rules to the table.

```
/* modified krx12303.c */
#include <stdio.h>

char p[] =
"0/!10\"@40\'@50.@01/@11*!2"
"1\"/41\'/5"          /* added by RAL */
"1./02*!32.!23/ 03*!33.!24\"@04\\@64.@45\'@05\\@75.@56.@47.@5";

int main(){int c,i,d;char s,n;s='0';while((c=getchar())
!=EOF){d=0;for(i=0;p[i]!='\0'&&d==0;i=i+4){if(p[i]==s&&
(p[i+1]==c||p[i+1]=='.')){if(p[i+2]=='@')putchar(c);else
if(p[i+2]=='/'){putchar('/');putchar(c);}else if(p[i+2]
==' ')putchar(' ');n=p[i+3];d=1;}}s=n;}return 0;}
/* end of modified krx12303.c */
```

uncomment02 (Lew Pitcher)

==========

uncomment11 (Chris Torek)

==========

These have the same problem (or non-problem, according to your point of view) as uncomment03. If it were regarded as a problem, it could probably be fixed quite easily, though not (I think) as neatly as with uncomment03; I haven't looked at these carefully enough to be sure.

uncomment01, uncomment10 (Ben Pfaff)

========== ==========

An oversight has the effect that if a slash in program text is followed by anything other than a star or another slash, the following character is dropped. For example, with input

```
int a = 4/2;
```

the output is

```
int a = 4/;
```

The correction is the same in both cases; replace

```
    /* Program text following a slash. */
    if (c == '*')
        state = COMMENT;
    else {
        putchar('/');
        if (c != '/')
            state = PROGRAM;
    }
```

by

```
    /* Program text following a slash. */
    if (c == '*')
        state = COMMENT;
    else {
        putchar('/');
        if (c != '/') {
            putchar(c);
            state = PROGRAM;
        }
    }
```

After this, these programs will have the same problem (or not) as the previous three.

uncomment12 (Chris Mears)

==========

This is a completely different kettle of fish. If you run this with Ben Pfaff's solution as input, the output is quite bizarre; some comments have just their initial and final

slashes removed, for instance. I've managed to find two things contributing to this. The first is illustrated by the input

```
int c = '/';
```

with output

```
int c = '';
```

This can be fixed by changing the lines

```
   case '/':
      if (state == string) {
```

to

```
   case '/':
      if (state == string || state == character) {
```

However, with or without this change, the input

char *p = "\\"; /* This is not a comment. */

is left unchanged. What happens is that the closing quote of the string literal isn't recognised as such because of the preceding backlash, despite the backslash before that. The handling of backslashes is split between three cases (at least), and is complicated enough that I don't feel competent to propose a remedy.

This program breaks most of the above submissions:

```
/* krx123tp.c - a test program to serve as input to krx123*.c
 *
 * This is a shameless copy of Ben Pfaff's solution, to which I have
 * added a few extra statements to further test the candidate programs
 * for this exercise. As Ben says, this program already contains lots
 * of examples of comments and not-quite-comments. I've just made it
```

```
 * a little tougher.
 *
 */

/* K&R2 1-23: Write a program to remove all comments from a C program.
   Don't forget to handle quoted strings and character constants
   properly.  C comments do not nest.

   This solution does not deal with other special cases, such as
   trigraphs, line continuation with \, or <> quoting on #include,
   since these aren't mentioned up 'til then in K&R2.  Perhaps this is
   cheating.

   Note that this program contains both comments and quoted strings of
   text that looks like comments, so running it on itself is a
   reasonable test.  It also contains examples of a comment that ends
   in a star and a comment preceded by a slash.  Note that the latter
   will break C99 compilers and C89 compilers with // comment
   extensions.

   Interface: The C source file is read from stdin and the
   comment-less output is written to stdout. **/

#include <stdio.h>

int
main(void)
{
    /* State machine's current state. */
    enum {
        PROGRAM,
        SLASH,
        COMMENT,
        STAR,
        QUOTE,
        LITERAL
    } state;

    /* If state == QUOTE, then ' or ".  Otherwise, undefined. */
    int quote;

    state = PROGRAM;
    for (;;) {
        int c = getchar();
```

```
if (c == EOF) {
    if (state == SLASH)
        putchar('/' //**/
               1 / 1 /'\1');
    break;
}

if(0)
  printf("%d\n", 6/'\2');
/* line of code, and comment, added by RJH 10 July 2000 */

switch (state) {
case SLASH:
    /* Program text following a slash. */
    if (c == "/*"[1]) {
        state = COMMENT;
        break;
    }
    putchar('/');
    state = PROGRAM;
    /* Fall through. */

case PROGRAM:
    /* Program text. */
    if (c == '\'' || c == '"') {
        quote = c;
        state = QUOTE;
        putchar(c);
    }
    else if (c == "/*"[0])
        state = SLASH;
    else
        putchar(c);
    break;

case COMMENT:
    /* Comment. */
    if (c == '*')
        state = STAR;
    break;

case STAR:
    /* Comment following a star. */
    if (c == '/')
```

```
                state = PROGRAM;
            else if (c != '*') {
                state = COMMENT;
                putchar (' ');
            }
            break;

        case QUOTE:
            /* Within quoted string or character constant. */
            putchar(c);
            if (c == '\\')
                state = LITERAL;
            else if (c == quote)
                state = PROGRAM;
            break;

        case LITERAL:
            /* Within quoted string or character constant, following \. */
            putchar(c);
            state = QUOTE;
            break;

        default:
            abort();
        }
    }

    return /* this comment added by RJH 10 July 2000 */ 0;
}

/*
   Local variables:
   compile-command: "checkergcc -W -Wall -ansi -pedantic knr123.c -o
knr123"
   End:
*/
```

Answer to Exercise 1-24, page 34

Write a program to check a C program for rudimentary syntax errors like unbalanced parentheses, brackets and braces. Don't forget about quotes, both single and double, escape sequences, and comments. (This program is hard if you do it in full generality.)

Rick Dearman's Category 0 solution:

```c
/*******************************************************
   KnR 1-24
   --------
   Write a program to check the syntax of a C program
   for matching {} () "" '' []

   Author: Rick Dearman
   email: rick@ricken.demon.co.uk

*******************************************************/
#include <stdio.h>

#define MAXLINE 1000 /* max input line size */
char line[MAXLINE]; /*current input line*/

int getline(void);  /* taken from the KnR book. */


int
main()
{
  int len=0;
  int t=0;
  int brace=0, bracket=0, parenthesis=0;
  int s_quote=1, d_quote=1;


  while ((len = getline()) > 0 )
    {
      t=0;
      while(t < len)
         {
          if( line[t] == '[')
            {
              brace++;
            }
          if( line[t] == ']')
            {
              brace--;
            }
          if( line[t] == '(')
            {
              parenthesis++;
```

```
          }
        if( line[t] == ')')
          {
            parenthesis--;
          }
        if( line[t] == '\'')
          {
            s_quote *= -1;
          }
        if( line[t] == '"')
          {
            d_quote *= -1;
          }
        t++;
      }
  }
 if(d_quote !=1)
  printf ("Mismatching double quote mark\n");
 if(s_quote !=1)
  printf ("Mismatching single quote mark\n");
 if(parenthesis != 0)
  printf ("Mismatching parenthesis\n");
 if(brace != 0)
  printf ("Mismatching brace mark\n");
 if(bracket != 0)
  printf ("Mismatching bracket mark\n");
 if( bracket==0 && brace==0 && parenthesis==0 && s_quote == 1 && d_quote
== 1)
     printf ("Syntax appears to be correct.\n");
 return 0;
}


/* getline: specialized version */
int getline(void)
{
 int c, i;
 extern char line[];

 for ( i=0;i<MAXLINE-1 && ( c=getchar()) != EOF && c != '\n'; ++i)
  line[i] = c;
 if(c == '\n')
  {
    line[i] = c;
```

```
      ++i;
    }
  line[i] = '\0';
  return i;

}
```

Stefan Farfeleder's Category 1 solution:

```
/* 1-24.c */

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

#define MAX_STACK 1024

enum
{
    CODE,       /* nothing of the following */
    COMMENT,    /* inside a comment */
    QUOTE1,     /* inside '' */
    QUOTE2      /* inside "" */
};

int main(void)
{
    int ch;
    int state = CODE;
    char stack[MAX_STACK];
    size_t top = 0; /* points to the top of the stack :-) */
    size_t line = 1;
    int error = 0;  /* for ok-message */

    while ((ch = getchar()) != EOF)
    {
        if (ch == '\n')
        {
            line++;
        }

        switch (state)
        {
        case CODE:
            if (ch == '\'')
```

```
{
    state = QUOTE1;
}
else if (ch == '"')
{
    state = QUOTE2;
}
else if (ch == '/')
{
    int second = getchar();

    if (second == '*')
    {
        state = COMMENT;
    }
    else
    {
        ungetc(second, stdin);
    }
}
else if (ch == '(' || ch == '[' || ch == '{')
{
    if (top < MAX_STACK)
    {
        stack[top++] = ch;
    }
    else
    {
        printf("Stack too small!\n");
        return EXIT_FAILURE; /* exit gracefully :-) */
    }
}
else if (ch == ')' || ch == ']' || ch == '}')
{
    if (top == 0) /* found closing brace but stack is empty */
    {
        printf("Line %lu: Closing '%c' found without "
               "counterpart.\n", (unsigned long)line, ch);
        error = 1;
    }
    else
    {
        char open = stack[--top];
```

```
                if ((ch == ')' && open != '(') ||
                    (ch == ']' && open != '[') ||
                    (ch == '}' && open != '{'))
                {
                    printf("Line %lu: Closing '%c' does not match "
                        "opening '%c'.\n", (unsigned long)line, ch,
open);
                    error = 1;
                }
            }
        }
        break;
    case COMMENT:
        if (ch == '*')
        {
            int second = getchar();

            if (second == '/')
            {
                state = CODE;
            }
            else
            {
                ungetc(second, stdin);
            }
        }
        break;
    case QUOTE1:
        if (ch == '\\')
        {
            (void)getchar(); /* an escaped char inside '' throw it away
*/
        }
        else if (ch == '\'')
        {
            state = CODE;
        }
        break;
    case QUOTE2:
        if (ch == '\\')
        {
            (void)getchar(); /* an escaped char inside "" throw it away
*/
        }
```

```
            else if (ch == '"')
            {
                state = CODE;
            }
            break;
        }
    }

    if (state == COMMENT)
    {
        printf("Code ends inside comment!\n");
    }
    else if (state == QUOTE1)
    {
        printf("Code ends inside single quotes!\n");
    }
    else if (state == QUOTE2)
    {
        printf("Code ends inside double quotes!\n");
    }
    else if (top == 0 && error == 0)
    {
        printf("Code seems to be ok.\n");
    }
    if (top > 0) /* still something in the stack */
    {
        size_t i;
        for (i = 0; i < top; i++)
        {
            printf("Opening '%c' found without counterpart.\n", stack[i]);
        }
    }

    return 0;
}
```

Stig Brautaset's Cat 1 solution:

```
/* This is my first rudimentary C syntax checker. It checks for syntax
errors,
 * like closing a set of brackets using the wrong type. It is not *very*
good
 * at it, but it does not bother about comments, and it does know something
```

```
 * about escape sequences and character strings/constants.
 *
 * It uses a simple static stack to keep track of the braces, and it also
uses
 * a stack to keep track of the errors on each line. Someday I might change
 * that to use a queue for the error-tracking, because as it is now, it
outputs
 * the rightmost error on the line first, and then it steps leftwards (if
there
 * is more than one error on each line).
 *
 * I might also implement my dynamically allocated stack and queue
implementa-
 * tions, so that running out of space in the stack is not an issue. I
might
 * also skip it, since it has little to do with the exercise in question.
 *
 * The program is especially bad at error-recovery. If it finds an error,
(or
 * something it believes to be an error) subsequent errors reported might
be a
 * bit dubious.
 */

#include <stdio.h>

#define MAXVAL 1000
#define MAXLINE 1000

typedef struct {
        int top;
        int val[MAXVAL];
        int pos[MAXVAL];
} stackstr;

/* very simple stack push function */
int push(stackstr *stk, int foo, int bar)
{
        if (stk->top == MAXVAL) {
                printf("stack overflow. NOT putting more values on the
stack.\n");
                return 1;
        }
        stk->val[stk->top] = foo;
```

```
        stk->pos[stk->top] = bar;
        stk->top++;

        return 0;
}

/* very simple function to pop values off a stack */
int pop(stackstr *stk, int *foo, int *bar)
{
        if (stk->top == 0) {
                return 1;
        }
        stk->top--;
        *foo = stk->val[stk->top];
        *bar = stk->pos[stk->top];

        return 0;
}

/* we go through the input one line at a time, and this function
 * gets the line to test
 */
int getline(char *s, int lim)
{
        int i, c;

        for (i = 0; i < lim - 1 && (c = getchar()) != EOF && c != '\n';
i++)
                *(s + i) = c;

        if (c == '\n')
                *(s + i++) = c;
        *(s + i) = '\0';

        return i;
}

void scanline(stackstr *stk, stackstr *errstk, char *s, int len)
{
        int i, c, d, foo;
        static int string = 0, comment = 0, isconst = 0, escape = 0;

        for (i = 0; i < len; i++) {
                c = *(s + i);
```

```
		if (!comment) {
			if (c == '\\') { /* we have an escape */
				/* test for a valid escape sequence */
				if ((d = *(s + ++i)) == '\\' || d == 'n'
|| d == '0' || d == 'r' || d == '?'
					|| d == 't' || d == '\'' || d ==
'\"' || d == 'b' || d == 'x') {
					continue; /* ok, valid escape
sequence -- don't bother about it */
				} else {
					push(errstk, 5, i); /* illigal
escape sequence */
				}
			} else if (c == '\"') { /* is it a text string then?
*/
			if (!string)
					string = 1;
				else
					string = 0;
			} else if (c == '\'') { /* is it a constant? */
				if (!isconst)
					isconst = 1;
				else
					isconst = 0;
			}
		}

		if (!isconst && !string && !comment && c == '/') {
			if ((d = *(s + ++i)) == '*')
				comment = 1;
		} else if (comment && c == '*') {
			if ((d = *(s + ++i)) == '/') {
				comment = 0;
			continue; /* done with the comment stuff -- start
over */
			}
		}

		/* only bother about ({[ ]})'s that's not in
		 * a string, constant or comment
		 */
		if (!isconst && !string && !comment) {
			if (c == '(' || c == '{' || c == '[') {
```

```
                        push(stk, c, 0);
                } else if (c == ']' || c == '}' || c == ')') {
                        if (pop(stk, &d, &foo)) {
                                push(errstk, 4, i);
                        }
                        if (c == ')' && d != '(') {
                                push(stk, d, 0);
                                push(errstk, 1, i);
                        } else if (c == ']' && d != '[') {
                                push(stk, d, 0);
                                push(errstk, 2, i);
                        } else if (c == '}' && d != '{') {
                                push(stk, d, 0);
                                push(errstk, 3, i);
                        }
                }
        }
}


/* print errors on the line (if there were any) */
void print_err(stackstr *errstk, int lineno)
{
        int errno, pos;

        /* yes I know... this way the errors come "backwards" :) */
        while (!pop(errstk, &errno, &pos)) {
                printf("on line number %d: ", lineno);
                switch(errno) {
                case 1:
                        printf("closing unopened parantheses,
column %d\n", pos+1);
                        break;
                case 2:
                        printf("closing unopened square bracket,
column %d\n", pos+1);
                        break;
        case 3:
                        printf("closing unopened curly braces,
column %d\n", pos+1);
                case 4:
```

```
                        printf("trying to close unopened block/control
structure, column %d\n", pos+1);
                        break;
        case 5:
                        printf("illigal escape sequence, column %d\n",
pos+1);
                        break;
                default:
                        printf("undeterminable error\n");
              break;
                }
        }
}

int main(void)
{
        stackstr errstk = {0}, stk = {0};
        int c, linenbr = 0, errcount = 0, linelen;
        char line[MAXLINE];

        while ((linelen = getline(line, MAXLINE)) > 0) {
                linenbr++;
                scanline(&stk, &errstk, line, linelen);
                if (errstk.top) {
                        print_err(&errstk, linenbr);
                        errcount++;
                }
        }

        if (errcount)
                printf("%d lines contained error(s)\n", errcount);
        else
                printf("Well, *I* didn't find any syntax errors, but don't
take my word for it...:)\n");

        return 0;
}
```

Answer to Exercise 2-1, page 36

Write a program to determine the ranges of `char` , `short` , `int` , and `long` variables, both `signed` and `unsigned` , by printing appropriate values from standard headers and by direct computation. Harder if you compute them: determine the ranges of the various floating-point types.

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

int
main ()
{
  printf("Size of Char %d\n", CHAR_BIT);
  printf("Size of Char Max %d\n", CHAR_MAX);
  printf("Size of Char Min %d\n", CHAR_MIN);
  printf("Size of int min %d\n", INT_MIN);
  printf("Size of int max %d\n", INT_MAX);
  printf("Size of long min %ld\n", LONG_MIN);      /* RB */
  printf("Size of long max %ld\n", LONG_MAX);      /* RB */
  printf("Size of short min %d\n", SHRT_MIN);
  printf("Size of short max %d\n", SHRT_MAX);
  printf("Size of unsigned char %u\n", UCHAR_MAX);  /* SF */
  printf("Size of unsigned long %lu\n", ULONG_MAX); /* RB */
  printf("Size of unsigned int %u\n", UINT_MAX);    /* RB */
  printf("Size of unsigned short %u\n", USHRT_MAX); /* SF */

  return 0;
}
```

Answer to Exercise 2-2, page 42

Exercise 2-2 discusses a `for` loop from the text. Here it is:

```c
  for(i=0; i<lim-1 && (c=getchar()) != '\n' && c != EOF; ++i)
    s[i] = c;
```

Write a loop equivalent to the `for` loop above without using `&&` or `||`.

```c
#include <stdio.h>

#define MAX_STRING_LENGTH 100

int main(void)
{
```

```
        /*
        for (i = 0; i < lim-1 && (c=getchar()) != '\n' && c != EOF; ++i)
                s[i] = c;
        */

        int i = 0,
                lim = MAX_STRING_LENGTH,
                c;
        char s[MAX_STRING_LENGTH];

        while (i < (lim - 1))
        {
                c = getchar();

                if (c == EOF)
                        break;
                else if (c == '\n')
                        break;

                s[i++] = c;
        }

        s[i] = '\0';   /* terminate the string */

        return 0;
}
```

Here's a Category 1 solution from Craig Schroeder, which is not so much exegetic as - um - cute. :-)

```
#include <stdio.h>

#define lim 80

int main()
{
       int i, c;
       char s[lim];

       /* There is a sequence point after the first operand of ?: */

       for(i=0; i<lim-1 ? (c=getchar()) != '\n' ? c != EOF : 0 : 0 ; ++i)
              s[i] = c;
```

```
        return s[i] ^= s[i]; /* null terminate and return. */
}
```

Answer to Exercise 2-3, page 46

Write the function `htoi(s)`, which converts a string of hexadecimal digits (including an optional `0x` or `0X`) into its equivalent integer value. The allowable digits are `0` through `9`, `a` through `f`, and `A` through `F`.

Here's my solution:

```
/* Write the function htoi(s), which converts a string of hexadecimal
 * digits (including an optional 0x or 0X) into its equivalent integer
 * value. The allowable digits are 0 through 9, a through f, and
 * A through F.
 *
 * I've tried hard to restrict the solution code to use only what
 * has been presented in the book at this point (page 46). As a
 * result, the implementation may seem a little naive. Error
 * handling is a problem. I chose to adopt atoi's approach, and
 * return 0 on error. Not ideal, but the interface doesn't leave
 * me much choice.
 *
 * I've used unsigned int to keep the behaviour well-defined even
 * if overflow occurs. After all, the exercise calls for conversion
 * to 'an integer', and unsigned ints are integers!
 */

/* These two header files are only needed for the test driver */
#include <stdio.h>
#include <stdlib.h>

/* Here's a helper function to get me around the problem of not
 * having strchr
 */

int hexalpha_to_int(int c)
{
  char hexalpha[] = "aAbBcCdDeEfF";
  int i;
  int answer = 0;

  for(i = 0; answer == 0 && hexalpha[i] != '\0'; i++)
  {
```

```
    if(hexalpha[i] == c)
    {
      answer = 10 + (i / 2);
    }
  }

  return answer;
}

unsigned int htoi(const char s[])
{
  unsigned int answer = 0;
  int i = 0;
  int valid = 1;
  int hexit;

  if(s[i] == '0')
  {
    ++i;
    if(s[i] == 'x' || s[i] == 'X')
    {
      ++i;
    }
  }

  while(valid && s[i] != '\0')
  {
    answer = answer * 16;
    if(s[i] >= '0' && s[i] <= '9')
    {
      answer = answer + (s[i] - '0');
    }
    else
    {
      hexit = hexalpha_to_int(s[i]);
      if(hexit == 0)
      {
        valid = 0;
      }
      else
      {
        answer = answer + hexit;
      }
    }
```

```
    ++i;
  }

  if(!valid)
  {
    answer = 0;
  }

  return answer;
}

/* Solution finished. This bit's just a test driver, so
 * I've relaxed the rules on what's allowed.
 */

int main(void)
{
  char *endp = NULL;
  char *test[] =
  {
    "F00",
    "bar",
    "0100",
    "0x1",
    "0XA",
    "0X0C0BE",
    "abcdef",
    "123456",
    "0x123456",
    "deadbeef",
    "zog_c"
  };

  unsigned int result;
  unsigned int check;

  size_t numtests = sizeof test / sizeof test[0];

  size_t thistest;

  for(thistest = 0; thistest < numtests; thistest++)
  {
    result = htoi(test[thistest]);
```

```
    check = (unsigned int)strtoul(test[thistest], &endp, 16);

    if((*endp != '\0' && result == 0) || result == check)
    {
      printf("Testing %s. Correct. %u\n", test[thistest], result);
    }
    else
    {
      printf("Testing %s. Incorrect. %u\n", test[thistest], result);
    }
  }

  return 0;
}
```

And here's Marshall's:

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

long hchartoi (char hexdig, int pos);   /* converts a hex char to decimal
knowing its 0 based place value */
long htoi (char hexstring[]);             /* converts a string of hex bits
to integer ... */

int main(void)
{
  char *endp = NULL;
  char *test[] =
  {
    "F00",
    "bar",
    "0100",
    "0x1",
    "0XA",
    "0X0C0BE",
    "abcdef",
    "123456",
    "0x123456",
    "deadbeef",
```

```
    "zog_c"
  };

  long int result;
  long int check;

  size_t numtests = sizeof test / sizeof test[0];

  size_t thistest;

  for(thistest = 0; thistest < numtests; thistest++)
  {
    result = htoi(test[thistest]);
    check = strtol(test[thistest], &endp, 16);

    if((*endp != '\0' && result == -1) || result == check)
    {
      printf("Testing %s. Correct. %ld\n", test[thistest], result);
    }
    else
    {
      printf("Testing %s. Incorrect. %ld\n", test[thistest], result);
    }
  }

  return 0;
}

long htoi (char s[])
{

    char *p = &s[strlen(s)-1];
    long deci = 0, dig = 0;
    int pos = 0;

    while (p >= s) {

        if ((dig = hchartoi(*p, pos)) < 0 ) {
            printf("Error\n");
            return -1;

        }
        deci += dig;
        --p;
```

```
        ++pos;

    }
    return deci;
}

/* convert hex char to decimal value */
long hchartoi (char hexdig, int pos)
{

    char hexdigits[] = "0123456789ABCDEF";
    char *p = &hexdigits[0];
    long deci = 0;
    int i;

    while (*p != toupper(hexdig) && deci < 16) {

        ++p;
        ++deci;

    }
    if (*p == toupper(hexdig)) {
       for (i = 0; i < pos; i++)
          deci *= 16;
       return deci;

    }
    return -1;
}
```

Answer to Exercise 2-4, page 48

Write an alternate version of `squeeze(s1,s2)` that deletes each character in the string `s1` that matches any character in the string `s2` .

```
/*
 * Exercise 2-4 Page 48
 *
 * Write an alternate version of squeeze(s1,s2) that deletes each
 * character in s1 that matches any character in the string s2.
 *
 */

/* squeeze2: delete all characters occurring in s2 from string s1. */
```

```c
void squeeze2(char s1[], char s2[])
{
  int i, j, k;
  int instr2 = 0;

  for(i = j = 0; s1[i] != '\0'; i++)
  {
    instr2 = 0;
    for(k = 0; s2[k] != '\0' && !instr2; k++)
    {
      if(s2[k] == s1[i])
      {
        instr2 = 1;
      }
    }

    if(!instr2)
    {
      s1[j++] = s1[i];
    }
  }
  s1[j] = '\0';
}

/* test driver */

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

int main(void)
{
  char *leftstr[] =
  {
    "",
    "a",
    "antidisestablishmentarianism",
    "beautifications",
    "characteristically",
    "deterministically",
    "electroencephalography",
    "familiarisation",
    "gastrointestinal",
    "heterogeneousness",
```

```
  "incomprehensibility",
  "justifications",
  "knowledgeable",
  "lexicographically",
  "microarchitectures",
  "nondeterministically",
  "organizationally",
  "phenomenologically",
  "quantifications",
  "representationally",
  "straightforwardness",
  "telecommunications",
  "uncontrollability",
  "vulnerabilities",
  "wholeheartedly",
  "xylophonically", /* if there is such a word :-) */
  "youthfulness",
  "zoologically"
};
char *rightstr[] =
{
  "",
  "a",
  "the",
  "quick",
  "brown",
  "dog",
  "jumps",
  "over",
  "lazy",
  "fox",
  "get",
  "rid",
  "of",
  "windows",
  "and",
  "install",
  "linux"
};

char buffer[32];
size_t numlefts = sizeof leftstr / sizeof leftstr[0];
size_t numrights = sizeof rightstr / sizeof rightstr[0];
size_t left = 0;
```

```
  size_t right = 0;

  for(left = 0; left < numlefts; left++)
  {
    for(right = 0; right < numrights; right++)
    {
      strcpy(buffer, leftstr[left]);

      squeeze2(buffer, rightstr[right]);

      printf("[%s] - [%s] = [%s]\n", leftstr[left], rightstr[right],
buffer);
    }
  }
  return 0;
}
```

Answer to Exercise 2-5, page 48

Write the function `any(s1,s2)` , which returns the first location in the string `s1` where any character from the string `s2` occurs, or `-1` if `s1` contains no characters from `s2` . (The standard library function `strpbrk` does the same job but returns a pointer to the location.)

Here is my solution, which is very simple but quite naive and inefficient. It has a worst-case time complexity of O(nm) where n and m are the lengths of the two strings.

```
/*
 * Exercise 2-5 Page 48
 *
 * Write the function any(s1,s2), which returns the first location
 * in the string s1 where any character from the string s2 occurs,
 * or -1 if s1 contains no characters from s2. (The standard library
 * function strpbrk does the same job but returns a pointer to the
 * location.)
 *
 */

int any(char s1[], char s2[])
{
  int i;
```

```
  int j;
  int pos;

  pos = -1;

  for(i = 0; pos == -1 && s1[i] != '\0'; i++)
  {
    for(j = 0; pos == -1 && s2[j] != '\0'; j++)
    {
      if(s2[j] == s1[i])
      {
        pos = i;
      }
    }
  }

  return pos;
}

/* test driver */

/* We get a helpful boost for testing from the question text, because we
are
 * told that the function's behaviour is identical to strpbrk except that
it
 * returns a pointer instead of a position. We use this fact to validate
the
 * function's correctness.
 */

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

int main(void)
{
  char *leftstr[] =
  {
    "",
    "a",
    "antidisestablishmentarianism",
    "beautifications",
    "characteristically",
    "deterministically",
    "electroencephalography",
```

```
  "familiarisation",
  "gastrointestinal",
  "heterogeneousness",
  "incomprehensibility",
  "justifications",
  "knowledgeable",
  "lexicographically",
  "microarchitectures",
  "nondeterministically",
  "organizationally",
  "phenomenologically",
  "quantifications",
  "representationally",
  "straightforwardness",
  "telecommunications",
  "uncontrollability",
  "vulnerabilities",
  "wholeheartedly",
  "xylophonically",
  "youthfulness",
  "zoologically"
};
char *rightstr[] =
{
  "",
  "a",
  "the",
  "quick",
  "brown",
  "dog",
  "jumps",
  "over",
  "lazy",
  "fox",
  "get",
  "rid",
  "of",
  "windows",
  "and",
  "install",
  "linux"
};

size_t numlefts = sizeof leftstr / sizeof leftstr[0];
```

```
size_t numrights = sizeof rightstr / sizeof rightstr[0];
size_t left = 0;
size_t right = 0;

int passed = 0;
int failed = 0;

int pos = -1;
char *ptr = NULL;

for(left = 0; left < numlefts; left++)
{
  for(right = 0; right < numrights; right++)
  {
    pos = any(leftstr[left], rightstr[right]);
    ptr = strpbrk(leftstr[left], rightstr[right]);

    if(-1 == pos)
    {
      if(ptr != NULL)
      {
        printf("Test %d/%d failed.\n", left, right);
        ++failed;
      }
      else
      {
        printf("Test %d/%d passed.\n", left, right);
        ++passed;
      }
    }
    else
    {
      if(ptr == NULL)
      {
        printf("Test %d/%d failed.\n", left, right);
        ++failed;
      }
      else
      {
        if(ptr - leftstr[left] == pos)
        {
          printf("Test %d/%d passed.\n", left, right);
          ++passed;
        }
```

```
        else
        {
          printf("Test %d/%d failed.\n", left, right);
          ++failed;
        }
      }
    }
  }
  printf("\n\nTotal passes %d, fails %d, total tests %d\n",
        passed,
        failed,
        passed + failed);
  return 0;
}
```

Here's a much better solution, by Partha Seetala. This solution has a worst- case time complexity of only O(n + m) which is considerably better.

It works in a very interesting way. He first defines an array with one element for each possible character in the character set, and then takes the *second* string and 'ticks' the array at each position where the second string contains the character corresponding to that position. It's then a simple matter to loop through the first string, quitting as soon as he hits a 'ticked' position in the array.

```
#include <stdio.h> /* for NULL */

int any(char *s1, char *s2)
{
       char array[256]; /* rjh comments
                        * (a) by making this char array[256] = {0}; the first
loop becomes unnecessary.
                        * (b) for full ANSIness, #include <limits.h>, make
the array unsigned char,
                        *    cast as required, and specify an array size
of UCHAR_MAX + 1.
                        * (c) the return statements' (parentheses) are not
required.
                        */
       int  i;
       if (s1 == NULL) {
              if (s2 == NULL) {
```

```
                return(0);
        } else {
                return(-1);
        }
    }

    for(i = 0; i < 256; i++) {
        array[i] = 0;
    }

    while(*s2 != '\0') {
        array[*s2] = 1;
        s2++;
    }

    i = 0;
    while(s1[i] != '\0') {
        if (array[s1[i]] == 1) {
                return(i);
        }
        i++;
    }
    return(-1);
}

/* test driver by Richard Heathfield */

/* We get a helpful boost for testing from the question text, because we
are
 * told that the function's behaviour is identical to strpbrk except that
it
 * returns a pointer instead of a position. We use this fact to validate
the
 * function's correctness.
 */

#include <string.h>

int main(void)
{
  char *leftstr[] =
  {
    "",
    "a",
```

```
  "antidisestablishmentarianism",
  "beautifications",
  "characteristically",
  "deterministically",
  "electroencephalography",
  "familiarisation",
  "gastrointestinal",
  "heterogeneousness",
  "incomprehensibility",
  "justifications",
  "knowledgeable",
  "lexicographically",
  "microarchitectures",
  "nondeterministically",
  "organizationally",
  "phenomenologically",
  "quantifications",
  "representationally",
  "straightforwardness",
  "telecommunications",
  "uncontrollability",
  "vulnerabilities",
  "wholeheartedly",
  "xylophonically",
  "youthfulness",
  "zoologically"
};
char *rightstr[] =
{
  "",
  "a",
  "the",
  "quick",
  "brown",
  "dog",
  "jumps",
  "over",
  "lazy",
  "fox",
  "get",
  "rid",
  "of",
  "windows",
  "and",
```

```
  "install",
  "linux"
};

size_t numlefts = sizeof leftstr / sizeof leftstr[0];
size_t numrights = sizeof rightstr / sizeof rightstr[0];
size_t left = 0;
size_t right = 0;

int passed = 0;
int failed = 0;

int pos = -1;
char *ptr = NULL;

for(left = 0; left < numlefts; left++)
{
  for(right = 0; right < numrights; right++)
  {
    pos = any(leftstr[left], rightstr[right]);
    ptr = strpbrk(leftstr[left], rightstr[right]);

    if(-1 == pos)
    {
      if(ptr != NULL)
      {
        printf("Test %d/%d failed.\n", left, right);
        ++failed;
      }
      else
      {
        printf("Test %d/%d passed.\n", left, right);
        ++passed;
      }
    }
    else
    {
      if(ptr == NULL)
      {
        printf("Test %d/%d failed.\n", left, right);
        ++failed;
      }
      else
      {
```

```
        if(ptr - leftstr[left] == pos)
        {
          printf("Test %d/%d passed.\n", left, right);
          ++passed;
        }
        else
        {
          printf("Test %d/%d failed.\n", left, right);
          ++failed;
        }
      }
    }
  }
  printf("\n\nTotal passes %d, fails %d, total tests %d\n",
        passed,
        failed,
        passed + failed);
  return 0;
}
```

Answer to Exercise 2-6, page 49

Write a function `setbits(x,p,n,y)` that returns `x` with the `n` bits that begin at position `p` set to the rightmost `n` bits of `y`, leaving the other bits unchanged.

This one's scary.

```
#include <stdio.h>

unsigned setbits(unsigned x, int p, int n, unsigned y)
{
  return (x & ((~0 << (p + 1)) | (~(~0 << (p + 1 - n))))) | ((y & ~(~0
<< n)) << (p + 1 - n));
}

int main(void)
{
  unsigned i;
  unsigned j;
  unsigned k;
  int p;
  int n;
```

```
  for(i = 0; i < 30000; i += 511)
  {
    for(j = 0; j < 1000; j += 37)
    {
      for(p = 0; p < 16; p++)
      {
        for(n = 1; n <= p + 1; n++)
        {
          k = setbits(i, p, n, j);
          printf("setbits(%u, %d, %d, %u) = %u\n", i, p, n, j, k);
        }
      }
    }
  }
  return 0;
}
```

Answer to Exercise 2-7, page 49

Write a function `invert(x,p,n)` that returns `x` with the `n` bits that begin at position `p` inverted (i.e., 1 changed into 0 and vice versa), leaving the others unchanged.

```
unsigned invert(unsigned x, int p, int n)
{
    return x ^ (~(~0U << n) << p);
}

/* main driver added, in a hurry while tired, by RJH. Better test driver
suggestions are welcomed! */

#include <stdio.h>

int main(void)
{
  unsigned x;
  int p, n;

  for(x = 0; x < 700; x += 49)
    for(n = 1; n < 8; n++)
      for(p = 1; p < 8; p++)
        printf("%u, %d, %d: %u\n", x, n, p, invert(x, n, p));
  return 0;
}
```

Answer to Exercise 2-8, page 49

Write a function `rightrot(x,n)` that returns the value of the integer x rotated to the right by n bit positions.

Greg's Cat 0 solution

```
unsigned rightrot(unsigned x, unsigned n)
{
    while (n > 0) {
        if ((x & 1) == 1)
            x = (x >> 1) | ~(~0U >> 1);
        else
            x = (x >> 1);
        n--;
    }
    return x;
}

/* main driver added, in a hurry while tired, by RJH. Better test driver
suggestions are welcomed! */

#include <stdio.h>

int main(void)
{
  unsigned x;
  int n;

  for(x = 0; x < 700; x += 49)
    for(n = 1; n < 8; n++)
      printf("%u, %d: %u\n", x, n, rightrot(x, n));
  return 0;
}
```

Here's Bob Wightman's Cat 1 solution:

```
/* K&R exercise 2-8

It is class 1 due to the /sizeof/ operator (CHAR_BIT is introduced with
```

```
<limits.h> in Chapter 1). I could have used the conditional operator but
thought that this is clearer.

Notes:
1. Implicit int removed (not absolutely necessary but...)
2. Checks for the size of the shift and reduces it to the range 0 -
(number of bits in an int) - 1 This is to avoid right shifting the
number into oblivion.
3. If either the value or the shift is zero then nothing need to be done
to the parameter so just return it.

*/

unsigned int rightrot(unsigned int x, unsigned int n)
{
   /* calculate number of bits in type */
   size_t s = sizeof(x) * CHAR_BIT;
   size_t p;

   /* limit shift to range 0 - (s - 1) */
   if(n < s)
      p = n;
   else
      p = n % s;

   /* if either is zero then the original value is unchanged */
   if((0 == x) || (0 == p))
      return x;

   return (x >> p) | (x << (s - p));
}

/* Driver based on yours but runs the shift values beyond the size of an
unsigned integer on any system */

int main(void)
{
   unsigned int val;
   unsigned int pos;
   unsigned int max = sizeof (pos) * CHAR_BIT + 1;

   for(val = 0; val < 700; val += 49)
   {
      for(pos = 0; pos < max; ++pos)
```

```
    {
        printf("%u, %d: %u\n", x, n, rightrot(val, pos));
    }
  }
}
```

Answer to Exercise 2-9, page 51

In a two's complement number system, `x &= (x-1)` deletes the rightmost 1-bit in `x`. Explain why. Use this observation to write a faster version of `bitcount`.

bitcount is written on p.50 as this:

```
/* bitcount:  count 1 bits in x */
int bitcount(unsigned x)
{
    int b;

    for (b = 0; x != 0; x >>= 1)
        if (x & 01)
            b++;
    return b;
}
```

Answer: If x is odd, then (x-1) has the same bit representation as x except that the rightmost 1-bit is now a 0. In this case, (x & (x-1)) == (x-1). If x is even, then the representation of (x-1) has the rightmost zeros of x becoming ones and the rightmost one becoming a zero. Anding the two clears the rightmost 1-bit in x and all the rightmost 1-bits from (x-1). Here's the new version of bitcount:

```
/* bitcount:  count 1 bits in x */
int bitcount(unsigned x)
{
    int b;

    for (b = 0; x != 0; x &= (x-1))
        b++;
    return b;
}
```

Answer to Exercise 2-10, page 52

Rewrite the function lower, which converts upper case letters to lower case, with a conditional expression instead of `if-else` .

```
/*

  Exercise 2-10. Rewrite the function lower, which converts upper case
letters
                to lower case, with a conditional expression instead of
if-else.



  Assumptions : by conditional expression they mean an expression
involving a ternary operator.

  Author: Bryan Williams

*/

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

#define TEST
#define ORIGINAL          0
#define SOLUTION          1
#define PORTABLE_SOLUTION   0


/*
   ok, the original routine we are trying to convert looks like this..
*/
#if ORIGINAL
/* lower: convert c to lower case; ASCII only */
int lower(int c)
{
  if(c >= 'A' && c <= 'Z')
    return c + 'a' - 'A';
  else
    return c;
}
#endif

/*
```

```c
   the natural solution for simply making this a conditional (ternary)
return instead of an
   if ... else ...
*/
#if SOLUTION
/* lower: convert c to lower case; ASCII only */
int lower(int c)
{
  return c >= 'A' && c <= 'Z' ? c + 'a' - 'A' : c;
}
#endif



/*
   the more portable solution, requiring string.h for strchr but keeping
the idea of a
   conditional return.
*/
#if PORTABLE_SOLUTION
/* lower: convert c to lower case */
int lower(int c)
{
  char *Uppercase = "ABCDEFGHIJKLMNOPQRSTUVWXYZ";
  char *Lowercase = "abcdefghijklmnopqrstuvwxyz";
  char *p = NULL;

  return NULL == (p = strchr(Uppercase, c)) ? c : *(Lowercase + (p -
Uppercase));
}
#endif



/*
    ok, this bit is just a test driver... exclude as required
*/
#ifdef TEST
int main(void)
{
  char *Tests = "AaBbcCD3EdFGHgIJKLhM2NOjPQRkSTlUVWfXYf0Z1";
  char *p = Tests;
  int Result = 0;
```

```
  while('\0' != *p)
  {
    Result = lower(*p);
    printf("[%c] gives [%c]\n", *p, Result);
    ++p;
  }

  /* and the obligatory boundary test */
  Result = lower(0);
  printf("'\\0' gives %d\n", Result);

  return 0;
}

#endif
```

Answer to Exercise 3-1, page 58

Our binary search makes two tests inside the loop, when one would suffice (at the price of more tests outside). Write a version with only one test inside the loop and measure the difference in run-time.

Paul Griffiths' solution (krx30100.c):

```
/* Solution by Paul Griffiths (paul@paulgriffiths.demon.co.uk) */

/*

  EX3_1.C
  =======

  Suggested solution to Exercise 3-1

*/

#include <stdio.h>
#include <time.h>

int binsearch(int x, int v[], int n);     /*  Original K&R function  */
int binsearch2(int x, int v[], int n);    /*  Our new function       */

#define MAX_ELEMENT 20000
```

```c
/*  Outputs approximation of processor time required
    for our two binary search functions. We search for
    the element -1, to time the functions' worst case
    performance (i.e. element not found in test data)   */

int main(void) {
    int testdata[MAX_ELEMENT];
    int index;               /*  Index of found element in test data  */
    int n = -1;              /*  Element to search for  */
    int i;
    clock_t time_taken;

    /*  Initialize test data  */

    for ( i = 0; i < MAX_ELEMENT; ++i )
        testdata[i] = i;


    /*  Output approximation of time taken for
        100,000 iterations of binsearch()      */

    for ( i = 0, time_taken = clock(); i < 100000; ++i ) {
        index = binsearch(n, testdata, MAX_ELEMENT);
    }
    time_taken = clock() - time_taken;

    if ( index < 0 )
        printf("Element %d not found.\n", n);
    else
        printf("Element %d found at index %d.\n", n, index);

    printf("binsearch() took %lu clocks (%lu seconds)\n",
          (unsigned long) time_taken,
          (unsigned long) time_taken / CLOCKS_PER_SEC);


    /*  Output approximation of time taken for
        100,000 iterations of binsearch2()       */

    for ( i = 0, time_taken = clock(); i < 100000; ++i ) {
        index = binsearch2(n, testdata, MAX_ELEMENT);
    }
    time_taken = clock() - time_taken;
```

```
    if ( index < 0 )
        printf("Element %d not found.\n", n);
    else
        printf("Element %d found at index %d.\n", n, index);

    printf("binsearch2() took %lu clocks (%lu seconds)\n",
           (unsigned long) time_taken,
           (unsigned long) time_taken / CLOCKS_PER_SEC);

    return 0;
}


/*  Performs a binary search for element x
       in array v[], which has n elements     */

int binsearch(int x, int v[], int n) {
    int low, mid, high;

    low = 0;
    high = n - 1;
    while ( low <= high ) {
        mid = (low+high) / 2;
        if ( x < v[mid] )
            high = mid - 1;
        else if ( x > v[mid] )
            low = mid + 1;
        else
            return mid;
    }
    return -1;
}


/*  Implementation of binsearch() using
    only one test inside the loop       */

int binsearch2(int x, int v[], int n) {
    int low, high, mid;

    low = 0;
    high = n - 1;
    mid = (low+high) / 2;
```

```
    while ( low <= high && x != v[mid] ) {
        if ( x < v[mid] )
            high = mid - 1;
        else
            low = mid + 1;
        mid = (low+high) / 2;
    }
    if ( x == v[mid] )
        return mid;
    else
        return -1;
}
```

Colin Barker's solution (krx30101.c):

```
/* Solution by Colin Barker (colin.barker@wanadoo.fr)
 * using the driver from the solution by Paul Griffiths.
 */

/*

  EX3_1.C
  =======

  Suggested solution to Exercise 3-1

*/

#include <stdio.h>
#include <time.h>

int binsearch(int x, int v[], int n);    /*  Original K&R function  */
int binsearch2(int x, int v[], int n);    /*  Our new function      */

#define MAX_ELEMENT 20000


/*  Outputs approximation of processor time required
    for our two binary search functions. We search for
    the element -1, to time the functions' worst case
    performance (i.e. element not found in test data)   */
```

```c
int main(void) {
    int testdata[MAX_ELEMENT];
    int index;               /*  Index of found element in test data  */
    int n = -1;              /*  Element to search for  */
    int i;
    clock_t time_taken;

    /*  Initialize test data  */

    for ( i = 0; i < MAX_ELEMENT; ++i )
        testdata[i] = i;


    /*  Output approximation of time taken for
        100,000 iterations of binsearch()      */

    for ( i = 0, time_taken = clock(); i < 100000; ++i ) {
        index = binsearch(n, testdata, MAX_ELEMENT);
    }
    time_taken = clock() - time_taken;

    if ( index < 0 )
        printf("Element %d not found.\n", n);
    else
        printf("Element %d found at index %d.\n", n, index);

    printf("binsearch() took %lu clocks (%lu seconds)\n",
           (unsigned long) time_taken,
           (unsigned long) time_taken / CLOCKS_PER_SEC);


    /*  Output approximation of time taken for
        100,000 iterations of binsearch2()       */

    for ( i = 0, time_taken = clock(); i < 100000; ++i ) {
        index = binsearch2(n, testdata, MAX_ELEMENT);
    }
    time_taken = clock() - time_taken;

    if ( index < 0 )
        printf("Element %d not found.\n", n);
    else
        printf("Element %d found at index %d.\n", n, index);
```

```
    printf("binsearch2() took %lu clocks (%lu seconds)\n",
           (unsigned long) time_taken,
           (unsigned long) time_taken / CLOCKS_PER_SEC);

    return 0;
}


/*  Performs a binary search for element x
       in array v[], which has n elements     */

int binsearch(int x, int v[], int n) {
    int low, mid, high;

    low = 0;
    high = n - 1;
    while ( low <= high ) {
        mid = (low+high) / 2;
        if ( x < v[mid] )
            high = mid - 1;
        else if ( x > v[mid] )
            low = mid + 1;
        else
            return mid;
    }
    return -1;
}

int binsearch2(int x, int v[], int n)
{
  int low, high, mid;

  low = -1;
  high = n;
  while (low + 1 < high) {
    mid = (low + high) / 2;
    if (v[mid] < x)
      low = mid;
    else
      high = mid;
  }
  if (high == n || v[high] != x)
    return -1;
  else
```

```
    return high;
}
```

Andrew Tesker's solution (krx30102.c):

```
/* Andrew Tesker
 *
 * krx30102.c
 */

#include <stdio.h>

/* find x in v[] */
int binsearch(int x, int v[], int n);

/*
  The main is here for the purpose of a built in test

 */


int main(void)
{
  int test[]={1,3,5,7,9,11,13};
  int i;
  for(i=(sizeof(test)/sizeof(int))-1; i>=0; --i)
    printf("looking for %d. Index=%d\n",test[i],binsearch(test[i], test,
sizeof(test)/sizeof(*test)));

  return 0;

}
/* n = size of array v */

int binsearch(int x, int v[], int n)
{
  int low, high, mid;

  low = 0;
  high = n-1;

  while(low < high) {
```

```
    mid = (low+high)/2;
    if(x <= v[mid])
      high=mid;

    else
      low = mid+1;
  }

  return (x == v[low])?low : -1;

}
```

Answer to Exercise 3-2, page 60

Write a function `escape(s,t)` that converts characters like newline and tab into visible escape sequences like `\n` and `\t` as it copies the string `t` to `s` . Use a `switch` . Write a function for the other direction as well, converting escape sequences into the real characters.

```
/*

  EX3_2.C
  =======

  Suggested solution to Exercise 3-2

*/

#include <stdio.h>

void escape(char * s, char * t);
void unescape(char * s, char * t);

int main(void) {
    char text1[50] = "\aHello,\n\tWorld! Mistakee\b was \"Extra
'e'\"!\n";
    char text2[51];

    printf("Original string:\n%s\n", text1);

    escape(text2, text1);
    printf("Escaped string:\n%s\n", text2);
```

```
    unescape(text1, text2);
    printf("Unescaped string:\n%s\n", text1);

    return 0;
}


/*  Copies string t to string s, converting special
    characters into their appropriate escape sequences.
    The "complete set of escape sequences" found in
    K&R Chapter 2 is used, with the exception of:

    \? \' \ooo \xhh

    as these can be typed directly into the source code,
    (i.e. without using the escape sequences themselves)
    and translating them is therefore ambiguous.        */

void escape(char * s, char * t) {
    int i, j;
    i = j = 0;

    while ( t[i] ) {

        /*  Translate the special character, if we have one  */

        switch( t[i] ) {
        case '\n':
            s[j++] = '\\';
            s[j] = 'n';
            break;

        case '\t':
            s[j++] = '\\';
            s[j] = 't';
            break;

        case '\a':
            s[j++] = '\\';
            s[j] = 'a';
            break;

        case '\b':
            s[j++] = '\\';
```

```
            s[j] = 'b';
            break;

        case '\f':
            s[j++] = '\\';
            s[j] = 'f';
            break;

        case '\r':
            s[j++] = '\\';
            s[j] = 'r';
            break;

        case '\v':
            s[j++] = '\\';
            s[j] = 'v';
            break;

        case '\\':
            s[j++] = '\\';
            s[j] = '\\';
            break;

        case '\"':
            s[j++] = '\\';
            s[j] = '\"';
            break;

        default:

            /*  This is not a special character, so just copy it  */

            s[j] = t[i];
            break;
        }
        ++i;
        ++j;
    }
    s[j] = t[i];    /*  Don't forget the null character  */
}


/*  Copies string t to string s, converting escape sequences
    into their appropriate special characters. See the comment
```

```
    for escape() for remarks regarding which escape sequences
    are translated.                                          */

void unescape(char * s, char * t) {
    int i, j;
    i = j = 0;

    while ( t[i] ) {
        switch ( t[i] ) {
        case '\\':

            /*  We've found an escape sequence, so translate it  */

            switch( t[++i] ) {
            case 'n':
                s[j] = '\n';
                break;

            case 't':
                s[j] = '\t';
                break;

            case 'a':
                s[j] = '\a';
                break;

            case 'b':
                s[j] = '\b';
                break;

            case 'f':
                s[j] = '\f';
                break;

            case 'r':
                s[j] = '\r';
                break;

            case 'v':
                s[j] = '\v';
                break;

            case '\\':
                s[j] = '\\';
```

```
                break;

            case '\"':
                s[j] = '\"';
                break;

            default:

                /*  We don't translate this escape
                    sequence, so just copy it verbatim  */

                s[j++] = '\\';
                s[j] = t[i];
            }
            break;

        default:

            /*  Not an escape sequence, so just copy the character  */

            s[j] = t[i];
        }
        ++i;
        ++j;
    }
    s[j] = t[i];    /*  Don't forget the null character  */
}
```

Answer to Exercise 3-3, page 63

Write a function `expand(s1,s2)` that expands shorthand notations like `a-z` in the string `s1` into the equivalent complete list `abc...xyz` in `s2`. Allow for letters of either case and digits, and be prepared to handle cases like `a-b-c` and `a-z0-9` and `-a-z`. Arrange that a leading or trailing `-` is taken literally.

```
/*

  EX3_3.C
  =======

  Suggested solution to Exercise 3-3

*/
```

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

void expand(char * s1, char * s2);

int main(void) {
   char *s[] = { "a-z-", "z-a-", "-1-6-",
                 "a-ee-a", "a-R-L", "1-9-1",
                 "5-5", NULL };
   char result[100];
   int i = 0;

   while ( s[i] ) {

      /*  Expand and print the next string in our array s[]  */

      expand(result, s[i]);
      printf("Unexpanded: %s\n", s[i]);
      printf("Expanded  : %s\n", result);
      ++i;
   }

   return 0;
}


/*  Copies string s2 to s1, expanding
   ranges such as 'a-z' and '8-3'    */

void expand(char * s1, char * s2) {
   static char upper_alph[27] = "ABCDEFGHIJKLMNOPQRSTUVWXYZ";
   static char lower_alph[27] = "abcdefghijklmnopqrstuvwxyz";
   static char digits[11]    = "0123456789";

   char * start, * end, * p;
   int i = 0;
   int j = 0;


   /*  Loop through characters in s2  */

   while ( s2[i] ) {
      switch( s2[i] ) {
```

```
        case '-':
           if ( i == 0 || s2[i+1] == '\0' ) {

              /*  '-' is leading or trailing, so just copy it  */

              s1[j++] = '-';
              ++i;
              break;
           }
           else {

               /*  We have a "range" to extrapolate. Test whether
                   the two operands are part of the same range. If
                   so, store pointers to the first and last characters
                   in the range in start and end, respectively. If
                   not, output and error message and skip this range.    */

              if ( (start = strchr(upper_alph, s2[i-1])) &&
                   (end   = strchr(upper_alph, s2[i+1])) )
                  ;
              else if ( (start = strchr(lower_alph, s2[i-1])) &&
                        (end   = strchr(lower_alph, s2[i+1])) )
                  ;
              else if ( (start = strchr(digits, s2[i-1])) &&
                        (end   = strchr(digits, s2[i+1])) )
                  ;
              else {

                 /*  We have mismatched operands in the range,
                     such as 'a-R', or '3-X', so output an error
                     message, and just copy the range expression.  */

                 fprintf(stderr, "EX3_3: Mismatched operands
'%c-%c'\n",
                               s2[i-1], s2[i+1]);
                 s1[j++] = s2[i-1];
                 s1[j++] = s2[i++];
                 break;
              }


              /*  Expand the range  */

              p = start;
```

```
            while ( p != end ) {
                s1[j++] = *p;
                if ( end > start )
                    ++p;
                else
                    --p;
            }
            s1[j++] = *p;
            i += 2;
        }
        break;

    default:
        if ( s2[i+1] == '-' && s2[i+2] != '\0' ) {

            /*  This character is the first operand in
                a range, so just skip it - the range will
                be processed in the next iteration of
                the loop.                               */

            ++i;
        }
        else {

            /*  Just a normal character, so copy it  */

            s1[j++] = s2[i++];
        }
        break;
    }
  }
  s1[j] = s2[i];   /*  Don't forget the null character  */
}
```

Answer to Exercise 3-4, page 64

Wayne Lubin's query involved Paul's discussion of two's complement. The text has now been corrected (by Paul).

In a two's complement number representation, our version of `itoa` does not handle the largest negative number, that is, the value of n equal to `-(2` to the power `(wordsize - 1))` . Explain why not. Modify it to print that value correctly regardless of the machine on which it runs.

Exercise 3-4 explanation: There are a number of ways of representing signed integers in binary, for example, signed-magnitude, excess-M, one's complement and two's complement. We shall restrict our discussion to the latter two. In a one's complement number representation, the binary represenation of a negative number is simply the binary representation of its positive counterpart, with the sign of all the bits switched. For instance, with 8 bit variables:

```
SIGNED  BINARY  UNSIGNED

  25   00011001    25
 -25   11100110   230

 127   01111111   127
-127   10000000   128
```

The implications of this are (amongst others) that there are two ways of representing zero (all zero bits, and all one bits), that the maximum range for a signed 8-bit number is -127 to 127, and that negative numbers are biased by (2^n - 1) (i.e. -I is represented by (2^n - 1) - (+I). In our example, so:

```
Bias = 2^8 - 1 = 255 = 11111111
Subtract 25         = 00011001
Equals              = 11100110
```

In a two's complement representation, negative numbers are biased by 2^n, e.g.:

```
Bias = 2^8  = 100000000
Subtract 25 =  00011001
Equals      =  11100111
```

In other words, to find the two's complement representation of a negative number, find the one's complement of it, and add one. The important thing to notice is that the range of an 8 bit variable using a two's complement representation is -128 to 127, as opposed to -127 to 127 using one's complement. Thus, the absolute value of the largest negative number cannot be represented (i.e. we cannot represent +128). Since the itoa() function in Chapter 3 handles negative numbers by reversing the sign of the number before processing, then adding a '-' to the string, passing the largest negative number will result it in being translated to itself:

```
-128           : 10000000
One's complement: 01111111
Subtract 1     : 10000000
```

Therefore, because (n /= 10) will be negative, the do-while loop will run once only,

and will place in the string a '-', followed by a single character, (INT_MIN % 10 + '0'). We can remedy these two bugs in the following way: 1 - change 'while ((n /= 10) > 0)' to 'while (n /= 10)'. Since any fractional part is truncated with integer division, n will eventually equal zero after successive divides by 10, and 'n /= 10' will evaluate to false sooner or later. 2 - change 'n % 10 + '0'' to 'abs(n % 10) + '0'', to get the correct character. EX3_4.C shows the revised function, which will run correctly regardless of the number representation.

```
/*

  EX3_4.C
  =======

  Suggested solution to Exercise 3-4

*/

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

void itoa(int n, char s[]);
void reverse(char s[]);

int main(void) {
    char buffer[20];

    printf("INT_MIN: %d\n", INT_MIN);
    itoa(INT_MIN, buffer);
    printf("Buffer : %s\n", buffer);

    return 0;
}

void itoa(int n, char s[]) {
    int i, sign;
    sign = n;

    i = 0;
    do {
        s[i++] = abs(n % 10) + '0';
    } while ( n /= 10 );
    if (sign < 0)
        s[i++] = '-';
```

```
    s[i] = '\0';
    reverse(s);
}

void reverse(char s[]) {
    int c, i, j;
    for ( i = 0, j = strlen(s)-1; i < j; i++, j--) {
        c = s[i];
        s[i] = s[j];
        s[j] = c;
    }
}
```

Answer to Exercise 3-5, page 64

Write the function `itob(n,s,b)` that converts the integer `n` into a base `b` character representation in the string `s` . In particular, `itob(n,s,16)` formats `n` as a hexadecimal integer in `s` .

```
/*

  EX3_5.C
  =======

  Suggested solution to Exercise 3-5

*/

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

    void itob(int n, char s[], int b);
void reverse(char s[]);

int main(void) {
    char buffer[10];
    int i;

    for ( i = 2; i <= 20; ++i ) {
        itob(255, buffer, i);
        printf("Decimal 255 in base %-2d : %s\n", i, buffer);
    }
```

```
    return 0;
}


/*  Stores a string representation of integer n
    in s[], using a numerical base of b. Will handle
    up to base-36 before we run out of digits to use.  */

void itob(int n, char s[], int b) {
    static char digits[] = "0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZ";
    int i, sign;

    if ( b < 2 || b > 36 ) {
        fprintf(stderr, "EX3_5: Cannot support base %d\n", b);
        exit(EXIT_FAILURE);
    }

    if ((sign = n) < 0)
        n = -n;
    i = 0;
    do {
        s[i++] = digits[n % b];
    } while ((n /= b) > 0);
    if (sign < 0)
        s[i++] = '-';
    s[i] = '\0';
    reverse(s);
}


/*  Reverses string s[] in place  */

void reverse(char s[]) {
    int c, i, j;
    for ( i = 0, j = strlen(s)-1; i < j; i++, j--) {
        c = s[i];
        s[i] = s[j];
        s[j] = c;
    }
}
```

Answer to Exercise 3-6, page 64

Write a version of `itoa` that accepts three arguments instead of two. The third argument is a minimum field width; the converted number must be padded with blanks on the left if necessary to make it wide enough.

```c
/*

  EX3_6.C
  =======

  Suggested solution to Exercise 3-6

*/

#include <stdio.h>
#include <limits.h>

void itoa(int n, char s[], int width);
void reverse(char s[]);

int main(void) {
    char buffer[20];

    itoa(INT_MIN, buffer, 7);
    printf("Buffer:%s\n", buffer);

    return 0;
}

void itoa(int n, char s[], int width) {
    int i, sign;

    if ((sign = n) < 0)
        n = -n;
    i = 0;
    do {
        s[i++] = n % 10 + '0';
        printf("%d %% %d + '0' = %d\n", n, 10, s[i-1]);
    } while ((n /= 10) > 0);
    if (sign < 0)
        s[i++] = '-';

    while (i < width )    /*  Only addition to original function  */
        s[i++] = ' ';
```

```
    s[i] = '\0';
    reverse(s);
}

void reverse(char s[]) {
    int c, i, j;
    for ( i = 0, j = strlen(s)-1; i < j; i++, j--) {
        c = s[i];
        s[i] = s[j];
        s[j] = c;
    }
}
```

Answer to Exercise 4-1, page 71

Write the function `strrindex(s,t)` , which returns the position of the rightmost occurrence of `t` in `s` , or -1 if there is none.

```
/* Test driver by Richard Heathfield
 * Solution (strrindex function) by Rick Dearman
 */

#include <stdio.h>

/* Write the function strrindex(s,t), which returns the position
** of the rightmost occurrence of t in s, or -1 if there is none.
*/

int strrindex( char s[], char t )
{
  int i;
  int count = -1;

  for(i=0; s[i] != '\0'; i++)
  {
    if(s[i] == t)
    {
      count = i;
    }
  }

  return count;
}
```

```c
typedef struct TEST
{
  char *data;
  char testchar;
  int expected;
} TEST;

int main(void)
{
  TEST test[] =
  {
    {"Hello world", 'o', 7},
    {"This string is littered with iiiis", 'i', 32},
    {"No 'see' letters in here", 'c', -1}
  };

  size_t numtests = sizeof test / sizeof test[0];
  size_t i;

  char ch = 'o';
  int pos;

  for(i = 0; i < numtests; i++)
  {
    pos = strrindex(test[i].data, test[i].testchar);

    printf("Searching %s for last occurrence of %c.\n",
          test[i].data,
          test[i].testchar);

    printf("Expected result: %d\n", test[i].expected);
    printf("%sorrect (%d).\n", pos == test[i].expected ? "C" : "Inc", pos);
    if(pos != -1)
    {
      printf("Character found was %c\n", test[i].data[pos]);
    }
  }

  return 0;
}
```

Answer to Exercise 4-2, page 73

Extend `atof` to handle scientific notation of the form `123.45e-6` where a floating-point number may be followed by e or E and an optionally signed exponent.

```
/*
**  Written by Dann Corbit as K&R 2, Exercise 4-2 (Page 73).
**  Keep in mind that this is *JUST* a student exercise, and is
**  light years away from being robust.
**
**  Actually, it's kind of embarassing, but I'm too lazy to fix it.
**
**  Caveat Emptor, not my fault if demons fly out of your nose,
**  and all of that.
*/
#include <ctype.h>
#include <limits.h>
#include <float.h>
#include <signal.h>
#include <stdio.h>

int my_atof(char *string, double *pnumber)
{
   /* Convert char string to double data type. */
   double         retval;
   double         one_tenth = 0.1;
   double         ten = 10.0;
   double         zero = 0.0;
   int           found_digits = 0;
   int           is_negative = 0;
   char         *num;

   /* Check pointers. */
   if (pnumber == 0) {
      return 0;
   }
   if (string == 0) {
      *pnumber = zero;
      return 0;
   }
   retval = zero;

   num = string;

   /* Advance past white space. */
   while (isspace(*num))
```

```
    num++;

/* Check for sign. */
if (*num == '+')
    num++;
else if (*num == '-') {
    is_negative = 1;
    num++;
}
/* Calculate the integer part. */
while (isdigit(*num)) {
    found_digits = 1;
    retval *= ten;
    retval += *num - '0';
    num++;
}

/* Calculate the fractional part. */
if (*num == '.') {
    double        scale = one_tenth;
    num++;
    while (isdigit(*num)) {
        found_digits = 1;
        retval += scale * (*num - '0');
        num++;
        scale *= one_tenth;
    }
}
/* If this is not a number, return error condition. */
if (!found_digits) {
    *pnumber = zero;
    return 0;
}
/* If all digits of integer & fractional part are 0, return 0.0 */
if (retval == zero) {
    *pnumber = zero;
    return 1;            /* Not an error condition, and no need to
                          * continue. */
}
/* Process the exponent (if any) */
if ((*num == 'e') || (*num == 'E')) {
    int           neg_exponent = 0;
    int           get_out = 0;
    long          index;
```

```
    long          exponent = 0;
    double        getting_too_big = DBL_MAX * one_tenth;
    double        getting_too_small = DBL_MIN * ten;

    num++;
    if (*num == '+')
        num++;
    else if (*num == '-') {
        num++;
        neg_exponent = 1;
    }
    /* What if the exponent is empty?  Return the current result. */
    if (!isdigit(*num)) {
        if (is_negative)
            retval = -retval;

        *pnumber = retval;

        return (1);
    }
    /* Convert char exponent to number <= 2 billion. */
    while (isdigit(*num) && (exponent < LONG_MAX / 10)) {
        exponent *= 10;
        exponent += *num - '0';
        num++;
    }

    /* Compensate for the exponent. */
    if (neg_exponent) {
        for (index = 1; index <= exponent && !get_out; index++)
            if (retval < getting_too_small) {
                get_out = 1;
                retval = DBL_MIN;
            } else
                retval *= one_tenth;
    } else
        for (index = 1; index <= exponent && !get_out; index++) {
            if (retval > getting_too_big) {
                get_out = 1;
                retval = DBL_MAX;
            } else
                retval *= ten;
        }
}
```

```
    if (is_negative)
        retval = -retval;

    *pnumber = retval;

    return (1);
}
/*
** Lame and evil wrapper function to give the exercise the requested
** interface.  Dann Corbit will plead innocent to the end.
** It's very existence means that the code is not conforming.
** Pretend you are a C library implementer, OK?  But you would fix
** all those bleeding gaps, I am sure.
*/
double atof(char *s)
{
    double        d = 0.0;
    if (!my_atof(s, &d))
    {
#ifdef DEBUG
        fputs("Error converting string in [sic] atof()", stderr);
#endif
        raise(SIGFPE);
    }
    return d;
}

#ifdef UNIT_TEST
char  *strings[] = {
    "1.0e43",
    "999.999",
    "123.456e-9",
    "-1.2e-3",
    "1.2e-3",
    "-1.2E3",
    "-1.2e03",
    "cat",
    "",
    0
};
int  main(void)
{
    int           i = 0;
    for (; *strings[i]; i++)
```

```
        printf("atof(%s) = %g\n", strings[i], atof(strings[i]));
    return 0;
}
#endif
```

Answer to Exercise 4-3, page 79

Given the basic framework, it's straightforward to extend the calculator. Add the modulus (%) operator and provisions for negative numbers.

In Bob's words: "Here's my attempt Adding the modulus is easily done by another case in main and using the fmod function. The standard library has been mentioned at this point so it should be valid to use this for type 0 compliance. math.h should be added to the list of #includes for fmod."

```
int main(void)
{
    int type;
    double op2;
    char s[MAXOP];
    int flag = TRUE;

    while((type = Getop(s)) != EOF)
    {
        switch(type)
        {
          /* other cases snipped for brevity */

           case '%':
               op2 = pop();
               if(op2)
                   push(fmod(pop(), op2));
               else
                   printf("\nError: Division by zero!");
               break;

        }
    }
    return EXIT_SUCCESS;
}
```

Bob goes on to say: "Deal with unary minus when retrieving tokens. This is based on the fact that a unary minus will have no intervening space between it and its operand."

```
/* Getop: get next operator or numeric operand. */
int Getop(char s[])
{
    #define PERIOD  '.'
    int i = 0;
    int c;
    int next;

    /* Skip whitespace */
    while((s[0] = c = getch()) == ' ' || c == '\t')
        ;
    s[1] = '\0';

    /* Not a number but may contain a unary minus. */
    if(!isdigit(c) && c != PERIOD && c != '-')
        return c;

    if(c == '-')
    {
        next = getch();
        if(!isdigit(next) && next != PERIOD)
        {
           return c;
        }
        c = next;
    }
    else
    {
        c = getch();
    }

    while(isdigit(s[++i] = c))
           c = getch();
    if(c == PERIOD)                  /* Collect fraction part. */
        while(isdigit(s[++i] = c = getch()))
                      ;
    s[i] = '\0';
    if(c != EOF)
        unGetch(c);
    return NUMBER;
}
```

Answer to Exercise 4-4, page 79

Add commands to print the top element of the stack without popping, to duplicate it, and to swap the top two elements. Add a command to clear the stack.

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

#define MAXOP 100
#define NUMBER  0
#define TRUE 1
#define FALSE 0

/* This programme is a basic calculator.

Extra cases have been added to:
1. Show the top item of the stack without permanently popping it.
2. Swap the top two items on the stack.
3. Duplicate the top item on the stack.
4. Clear the stack.

I have used functions for each of the new cases rather than have the
code inline in order to limit the physical size of the switch block.

In anticipation of the following exercise the following characters have
been used for the operations (in the same order as above): ? ~ # !
rather than use alphabetic characters.

It is actually rather difficult to be original in this exercise.

This is exercise 4-4 from Kernighan & Ritchie, page 79.

 */

int Getop(char s[]);
void push(double val);
double pop(void);
void showTop(void);
void duplicate(void);
void swapItems(void);
void clearStack();

int main(void)
{
```

```
int type;
double op2;
char s[MAXOP];
int flag = TRUE;

while((type = Getop(s)) != EOF)
{
    switch(type)
    {
        case NUMBER:
                        push(atof(s));
            break;
        case '+':
            push(pop() + pop());
            break;
        case '*':
            push(pop() * pop());
            break;
        case '-':
            op2 = pop();
            push(pop()- op2);
            break;
        case '/':
            op2 = pop();
            if(op2)
                push(pop() / op2);
            else
                printf("\nError: division by zero!");
            break;
        case '%':
            op2 = pop();
            if(op2)
                push(fmod(pop(), op2));
            else
                printf("\nError: division by zero!");
            break;
        case '?':
            showTop();
            break;
        case '#':
            duplicate();
            break;
        case '~':
            swapItems();
```

```
            break;
        case '!':
            clearStack();
        case '\n':
            printf("\n\t%.8g\n", pop());
            break;
        default:
            printf("\nError: unknown command %s.\n", s);
            break;
      }
   }
   return EXIT_SUCCESS;
}

#define MAXVAL 100

int sp = 0;         /* Next free stack position. */
double val[MAXVAL];  /* value stack. */

/* push: push f onto stack. */
void push(double f)
{
   if(sp < MAXVAL)
      val[sp++] = f;
   else
       printf("\nError: stack full can't push %g\n", f);
}

/*pop: pop and return top value from stack.*/
double pop(void)
{
   if(sp > 0)
      return val[--sp];
   else
   {
      printf("\nError: stack empty\n");
      return 0.0;
   }
}

void showTop(void)
{
   if(sp > 0)
      printf("Top of stack contains: %8g\n", val[sp-1]);
```

```
    else
        printf("The stack is empty!\n");
}


void duplicate(void)
{
    double temp = pop();

    push(temp);
    push(temp);
}

void swapItems(void)
{
    double item1 = pop();
    double item2 = pop();

    push(item1);
    push(item2);
}

/* pop only returns a value if sp is greater than zero. So setting the
stack pointer to zero will cause pop to return its error */

void clearStack(void)
{
    sp = 0;
}

int getch(void);
void unGetch(int);

/* Getop: get next operator or numeric operand. */
int Getop(char s[])
{
    int i = 0;
    int c;
    int next;

    /* Skip whitespace */
    while((s[0] = c = getch()) == ' ' || c == '\t')
        ;
    s[1] = '\0';
```

```
    /* Not a number but may contain a unary minus. */
    if(!isdigit(c) && c != '.' && c != '-')
        return c;

    if(c == '-')
    {
        next = getch();
        if(!isdigit(next) && next != '.')
        {
           return c;
        }
        c = next;
    }
    else
        c = getch();

    while(isdigit(s[++i] = c))
           c = getch();
    if(c == '.')                    /* Collect fraction part. */
        while(isdigit(s[++i] = c = getch()))
                        ;
    s[i] = '\0';
    if(c != EOF)
        unGetch(c);
    return NUMBER;
}

#define BUFSIZE 100

char buf[BUFSIZE];
int bufp = 0;

/* Getch: get a ( possibly pushed back) character. */
int getch(void)
{
     return (bufp > 0) ? buf[--bufp]: getchar();
}

/* unGetch: push character back on input. */
void unGetch(int c)
{
    if(bufp >= BUFSIZE)
        printf("\nUnGetch: too many characters\n");
```

```
    else
        buf[bufp++] = c;
}
```

Answer to Exercise 4-5, page 79

Add access to library functions like `sin` , `exp` , and `pow` . See `<math.h>` in Appendix B, Section 4.

```
#include<stdlib.h>
#include<stdio.h>
#include<ctype.h>
#include<math.h>
#include <string.h>

#define MAXOP 100
#define NUMBER      0
#define IDENTIFIER   1
#define TRUE 1
#define FALSE 0

/*

  The new additions deal with adding functions from math.h to the
  calculator.

  In anticipation of the following exercise the code deals with an
  identifier in the following manner:

  If the identifier is recognised as one of the supported mathematical
  functions then that function from the library is called. If the
  identifier is not one of the supported functions, even if it is a
  valid function from math.h it is ignored.

  The main changes are the introduction of another define value
  (IDENTIFIER) along with its associated case in the switch statement.
  Getop has also been changed to deal with reading in alphabetical
  characters.

  This is exercise 4-5 from Kernighan & Ritchie, page 79.

*/

int Getop(char s[]);
```

```c
void push(double val);
double pop(void);
void showTop(void);
void duplicate(void);
void swapItems(void);
void clearStack();
void dealWithName(char s[]);

int main(void)
{
   int type;
   double op2;
   char s[MAXOP];
   int flag = TRUE;

   while((type = Getop(s)) != EOF)
   {
      switch(type)
      {
      case NUMBER:
         push(atof(s));
         break;
      case IDENTIFIER:
         dealWithName(s);
         break;
      case '+':
         push(pop() + pop());
         break;
      case '*':
         push(pop() * pop());
         break;
      case '-':
         op2 = pop();
         push(pop()- op2);
         break;
      case '/':
         op2 = pop();
         if(op2)
            push(pop() / op2);
         else
            printf("\nError: division by zero!");
         break;
      case '%':
         op2 = pop();
```

```
        if(op2)
          push(fmod(pop(), op2));
        else
          printf("\nError: division by zero!");
        break;
      case '?':
        showTop();
        break;
      case '#':
        duplicate();
        break;
      case '~':
        swapItems();
        break;
      case '!':
        clearStack();
      case '\n':
        printf("\n\t%.8g\n", pop());
        break;
      default:
        printf("\nError: unknown command %s.\n", s);
        break;
      }
   }
   return EXIT_SUCCESS;
}

#define MAXVAL 100

int sp = 0;         /* Next free stack position. */
double val[MAXVAL];  /* value stack. */

/* push: push f onto stack. */
void push(double f)
{
   if(sp < MAXVAL)
     val[sp++] = f;
   else
     printf("\nError: stack full can't push %g\n", f);
}

/*pop: pop and return top value from stack.*/
double pop(void)
{
```

```
   if(sp > 0)
      return val[--sp];
   else
   {
      printf("\nError: stack empty\n");
      return 0.0;
   }
}

void showTop(void)
{
   if(sp > 0)
      printf("Top of stack contains: %8g\n", val[sp-1]);
   else
      printf("The stack is empty!\n");
}

/*
Alternatively:
void showTop(void)
{
double item = pop();
printf("Top of stack contains: %8g\n", item);
push(item);
}
*/


void duplicate(void)
{
   double temp = pop();

   push(temp);
   push(temp);
}

void swapItems(void)
{
   double item1 = pop();
   double item2 = pop();

   push(item1);
   push(item2);
}
```

```c
void clearStack(void)
{
   sp = 0;
}

/* deal with a string/name this may be either a maths function or for
future exercises: a variable */
void dealWithName(char s[])
{
   double op2;

   if( 0 == strcmp(s, "sin"))
      push(sin(pop()));
   else if( 0 == strcmp(s, "cos"))
      push(cos(pop()));
   else if (0 == strcmp(s, "exp"))
      push(exp(pop()));
   else if(!strcmp(s, "pow"))
   {
      op2 = pop();
      push(pow(pop(), op2));
   }
   else
      printf("%s is not a supported function.\n", s);
}

int getch(void);
void unGetch(int);

/* Getop: get next operator or numeric operand. */
int Getop(char s[])
{
   int i = 0;
   int c;
   int next;
   /*size_t len;*/

   /* Skip whitespace */
   while((s[0] = c = getch()) == ' ' || c == '\t')
      ;
   s[1] = '\0';

   if(isalpha(c))
```

```
  {
    i = 0;
    while(isalpha(s[i++] = c ))
      c = getch();
    s[i - 1] = '\0';
    if(c != EOF)
      unGetch(c);
    return IDENTIFIER;
  }

  /* Not a number but may contain a unary minus. */
  if(!isdigit(c) && c != '.' && c != '-')
    return c;

  if(c == '-')
  {
    next = getch();
    if(!isdigit(next) && next != '.')
    {
      return c;
    }
    c = next;
  }
  else
    c = getch();

  while(isdigit(s[++i] = c))
    c = getch();
  if(c == '.')              /* Collect fraction part. */
    while(isdigit(s[++i] = c = getch()))
      ;
    s[i] = '\0';
    if(c != EOF)
      unGetch(c);
    return NUMBER;
}

#define BUFSIZE 100

char buf[BUFSIZE];
int bufp = 0;

/* Getch: get a ( possibly pushed back) character. */
int getch(void)
```

```
{
   return (bufp > 0) ? buf[--bufp]: getchar();
}

/* unGetch: push character back on input. */
void unGetch(int c)
{
   if(bufp >= BUFSIZE)
      printf("\nUnGetch: too many characters\n");
   else
      buf[bufp++] = c;
}
```

Answer to Exercise 4-6, page 79

Add commands for handling variables. (It's easy to provide twenty-six variables with single-letter names.) Add a variable for the most recently printed value.

```
#include <stdlib.h>
#include <stdio.h>
#include <ctype.h>
#include <math.h>
#include <string.h>

#define MAXOP     100
#define NUMBER      0
/* 4-6 these are new for this exercise*/
#define IDENTIFIER   1
#define ENDSTRING    2
/* 4-6 end of new stuff */
#define TRUE        1
#define FALSE       0
#define MAX_ID_LEN  32
#define MAXVARS    30

/*
The new additions deal with adding variables to the calculator.

  If the identifier is recognised as one of the supported mathematical
  functions then that function from the library is called. If the
  identifier is not one of the supported functions, even if it is a
  valid function from math.h it is ignored.

  This is a class 1 solution as it uses structures which are not
```

```
  introduced until Chapter 6. This allows the use of "normal" names for
  variables rather than the suggested single letter though any
  identifier is limited to 31 characters.

  The main changes are:

    1. The introduction of two more define values (IDENTIFIER,
       ENDSTRING) along with associated cases in the switch statement.
    2. Getop has also been changed to deal with reading in alphabetical
       characters and coping with the '=' sign.
    3. A structure to hold the variable name and value.
    4. Another case in the switch statement to deal with the '=' sign.
    5. Altering the clearStack function to clear the array of structs as
       well as the stack.
    6. The '<' operator now prints the last accessed variable.

  Improvements:
  The code could be made class 0 by the use of "parallel" arrays for the
  names and values rather than a struct but this would be messy and is
  the situation that structs were made for.
  The use of a binary tree together with dynamically allocated memory
  would allow the arbitrary limit of 30 variables to be avoided. This
  would still be a class 1 solution.

  This is exercise 4-6 from Kernighan & Ritchie, page 79.
*/

/* 4-6 this is new for this program */
struct varType{
   char name[MAX_ID_LEN];
   double val;
};
/* 4-6 End of new stuff */

int Getop(char s[]);
void push(double val);
double pop(void);
void showTop(void);
void duplicate(void);
void swapItems(void);

/* 4-6 this is new for this program */
/* Changed clearStack(void) to clearStacks(struct varType var[])*/
void clearStacks(struct varType var[]);
```

```c
void dealWithName(char s[],  struct varType var[]);
void dealWithVar(char s[], struct varType var[]);

int pos = 0;
struct varType last;

/* 4-6 End of new stuff */

int main(void)
{
   int type;
   double op2;
   char s[MAXOP];
   struct varType var[MAXVARS];

   /* Use the new function here */
   clearStacks(var);

   while((type = Getop(s)) != EOF)
   {
      switch(type)
      {
      case NUMBER:
         push(atof(s));
         break;
      case IDENTIFIER:
         dealWithName(s, var);
         break;
      case '+':
         push(pop() + pop());
         break;
      case '*':
         push(pop() * pop());
         break;
      case '-':
         op2 = pop();
         push(pop()- op2);
         break;
      case '/':
         op2 = pop();
         if(op2)
            push(pop() / op2);
         else
            printf("\nError: division by zero!");
```

```
            break;
        case '%':
            op2 = pop();
            if(op2)
                push(fmod(pop(), op2));
            else
                printf("\nError: division by zero!");
            break;
        case '?':
            showTop();
            break;
        case '#':
            duplicate();
            break;
        case '~':
            swapItems();
            break;
        case '!':
            clearStacks(var);
            break;
        case '\n':
            printf("\n\t%.8g\n", pop());
            break;
            /* 4-6 this is new for this program */
        case ENDSTRING:
            break;
        case '=':
            pop();
            var[pos].val = pop();
            last.val = var[pos].val;
            push(last.val);
            break;
        case '<':
            printf("The last variable used was: %s (value == %g)\n",
                                        last.name, last.val);
            break;
            /* 4-6 End of new stuff */
        default:
            printf("\nError: unknown command %s.\n", s);
            break;
        }
    }
    return EXIT_SUCCESS;
}
```

```c
#define MAXVAL 100

int sp = 0;         /* Next free stack position. */
double val[MAXVAL];  /* value stack. */

/* push: push f onto stack. */
void push(double f)
{
   if(sp < MAXVAL)
      val[sp++] = f;
   else
      printf("\nError: stack full can't push %g\n", f);
}

/*pop: pop and return top value from stack.*/
double pop(void)
{
   if(sp > 0)
   {
      return val[--sp];
   }
   else
   {
      printf("\nError: stack empty\n");
      return 0.0;
   }
}

void showTop(void)
{
   if(sp > 0)
      printf("Top of stack contains: %8g\n", val[sp-1]);
   else
      printf("The stack is empty!\n");
}

/*
Alternatively:
void showTop(void)
{
double item = pop();
printf("Top of stack contains: %8g\n", item);
push(item);
```

```
}
*/

void duplicate(void)
{
   double temp = pop();

   push(temp);
   push(temp);
}

void swapItems(void)
{
   double item1 = pop();
   double item2 = pop();

   push(item1);
   push(item2);
}

/* 4-6 this is new for this program */
/* Altered to clear both the main stack and that of the variable
structure */
void clearStacks(struct varType var[])
{
   int i;

   /* Clear the main stack by setting the pointer to the bottom. */
   sp = 0;

   /* Clear the variables by setting the initial element of each name
   to the terminating character. */
   for( i = 0; i < MAXVARS; ++i)
   {
      var[i].name[0] = '\0';
      var[i].val = 0.0;
   }
}

/* a string/name may be either a maths function or a variable */
void dealWithName(char s[], struct varType var[])
{
   double op2;
```

```
   if(!strcmp(s, "sin"))
      push(sin(pop()));
   else if(!strcmp(s, "cos"))
      push(cos(pop()));
   else if (!strcmp(s, "exp"))
      push(exp(pop()));
   else if(!strcmp(s, "pow"))
   {
      op2 = pop();
      push(pow(pop(), op2));
   }
   /* Finally if it isn't one of the supported maths functions we have
a
      variable to deal with. */
   else
   {
      dealWithVar(s, var);
   }
}

/* Our identifier is not one of the supported maths function so we have
   to regard it as an identifier. */
void dealWithVar(char s[], struct varType var[])
{
   int i = 0;

   while(var[i].name[0] != '\0' && i < MAXVARS-1)
   {
      if(!strcmp(s, var[i].name))
      {
         strcpy(last.name, s);
                  last.val = var[i].val;
         push(var[i].val);
         pos = i;
         return;
      }
      i++;
   }

   /* variable name not found so add it */
   strcpy(var[i].name, s);
   /* And save it to the last variable */
   strcpy(last.name, s);
   push(var[i].val);
```

```
   pos = i;
}
/* 4-6 End of new stuff */

int getch(void);
void unGetch(int);

/* Getop: get next operator or numeric operand. */
int Getop(char s[])
{
   int i = 0;
   int c;
   int next;

   /* Skip whitespace */
   while((s[0] = c = getch()) == ' ' || c == '\t')
   {
      ;
   }
   s[1] = '\0';

   if(isalpha(c))
   {
      i = 0;
      while(isalpha(s[i++] = c ))
      {
         c = getch();
      }
      s[i - 1] = '\0';
      if(c != EOF)
         unGetch(c);
      return IDENTIFIER;
   }

   /* Not a number but may contain a unary minus. */
   if(!isdigit(c) && c != '.' && c != '-')
   {
      /* 4-6 Deal with assigning a variable. */
      if('=' == c && '\n' == (next = getch()))
      {
         unGetch('\0');
         return c;
      }
      if('\0' == c)
```

```
        return ENDSTRING;

      return c;
   }

   if(c == '-')
   {
      next = getch();
      if(!isdigit(next) && next != '.')
      {
         return c;
      }
      c = next;
   }
   else
   {
      c = getch();
   }

   while(isdigit(s[++i] = c))
   {
      c = getch();
   }
   if(c == '.')              /* Collect fraction part. */
   {
      while(isdigit(s[++i] = c = getch()))
         ;
   }
   s[i] = '\0';
   if(c != EOF)
      unGetch(c);
   return NUMBER;
}

#define BUFSIZE 100

int buf[BUFSIZE];
int bufp = 0;

/* Getch: get a ( possibly pushed back) character. */
int getch(void)
{
   return (bufp > 0) ? buf[--bufp]: getchar();
}
```

```
/* unGetch: push character back on input. */
void unGetch(int c)
{
   if(bufp >= BUFSIZE)
      printf("\nUnGetch: too many characters\n");
   else
      buf[bufp++] = c;
}
```

Answer to Exercise 4-7, page 79

Write a routine `ungets(s)` that will push back an entire string onto the input. Should `ungets` know about `buf` and `bufp` , or should it just use `ungetch` ?

```
/* K&R Exercise 4-7 */
/* Steven Huang */

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

#define BUFSIZE 100

char buf[BUFSIZE]; /* buffer for ungetch */
int bufp = 0; /* next free position in buf */

int getch(void) /* get a (possibly pushed back) character */
{
  return (bufp > 0) ? buf[--bufp] : getchar();
}

void ungetch(int c) /* push character back on input */
{
  if(bufp >= BUFSIZE)
    printf("ungetch: too many characters\n");
  else
    buf[bufp++] = c;
}

/*
   ungets() actually takes a little bit of thought.  Should the
   first character in "s" be sent to ungetch() first, or should
   it be sent last?  I assumed that most code calling getch()
```

```
   would be of this form:

     char array[...];
     int i;

     while (...) {
       array[i++] = getch();
     }

   In such cases, the same code might call ungets() as:

     ungets(array);

   and expect to repeat the while loop to get the same string
   back.  This requires that the last character be sent first
   to ungetch() first, because getch() and ungetch() work with
   a stack.

   To answer K&R2's additional question for this problem,
   it's usually preferable for something like ungets() to just
   build itself on top of ungetch().  This allows us to change
   ungetch() and getch() in the future, perhaps to use a linked
   list instead, without affecting ungets().
*/
void ungets(const char *s)
{
  size_t i = strlen(s);

  while (i > 0)
    ungetch(s[--i]);
}

int main(void)
{
  char *s = "hello, world.  this is a test.";
  int c;

  ungets(s);
  while ((c = getch()) != EOF)
    putchar(c);
  return 0;
}
```

Answer to Exercise 4-8, page 79

Suppose there will never be more than one character of pushback. Modify `getch` and `ungetch` accordingly.

```c
/* K&R Exercise 4-8 */
/* Steven Huang */

#include <stdio.h>

int buf = EOF; /* buffer for ungetch */

int getch(void) /* get a (possibly pushed back) character */
{
  int temp;

  if (buf != EOF) {
    temp = buf;
    buf = EOF;
  } else {
    temp = getchar();
  }
  return temp;
}

void ungetch(int c) /* push character back on input */
{
  if(buf != EOF)
    printf("ungetch: too many characters\n");
  else
    buf = c;
}

int main(void)
{
  int c;

  while ((c = getch()) != EOF) {
    if (c == '/') {
      putchar(c);
      if ((c = getch()) == '*') {
        ungetch('!');
      }
    }
    putchar(c);
  }
```

```
  return 0;
}
```

Answer to Exercise 4-12, page 88

Adapt the ideas of `printd` to write a recursive version of `atoi` ; that is, convert an integer into a string by calling a recursive routine.

```
/*

itoa() is non-standard, but defined on p.64 as having this prototype:

void itoa(int n, char s[])

Instead of this, I thought I'd use a different prototype (one I got from
the library manual of one of my compilers) since it includes all of the
above:

char *itoa(int value, char *digits, int base);

Description:  The itoa() function converts an integer value into an
ASCII string of digits.  The base argument specifies the number base for
the conversion.  The base must be a value in the range [2..36], where 2
is binary, 8 is octal, 10 is decimal, and 16 is hexadecimal.  The buffer
pointed to by digits must be large enough to hold the ASCII string of
digits plus a terminating null character.  The maximum amount of buffer
space used is the precision of an int in bits + 2 (one for the sign and
one for the terminating null).

Returns:  digits, or NULL if error.

*/

#include <stdlib.h>

char *utoa(unsigned value, char *digits, int base)
{
    char *s, *p;

    s = "0123456789abcdefghijklmnopqrstuvwxyz"; /* don't care if s is in
                                                 * read-only memory
                                                 */
    if (base == 0)
```

```
        base = 10;
    if (digits == NULL || base < 2 || base > 36)
        return NULL;
    if (value < (unsigned) base) {
        digits[0] = s[value];
        digits[1] = '\0';
    } else {
        for (p = utoa(value / ((unsigned)base), digits, base);
            *p;
            p++);
        utoa( value % ((unsigned)base), p, base);
    }
    return digits;
}

char *itoa(int value, char *digits, int base)
{
    char *d;
    unsigned u; /* assume unsigned is big enough to hold all the
                 * unsigned values -x could possibly be -- don't
                 * know how well this assumption holds on the
                 * DeathStation 9000, so beware of nasal demons
                 */

    d = digits;
    if (base == 0)
        base = 10;
    if (digits == NULL || base < 2 || base > 36)
        return NULL;
    if (value < 0) {
        *d++ = '-';
        u = -value;
    } else
        u = value;
    utoa(u, d, base);
    return digits;
}
```

Answer to Exercise 4-13, page 88

Write a recursive version of the function `reverse(s)` , which reverses the string `s` in place.

```c
/*

EXERCISE 4-13 Gregory Pietsch

*/

static void swap(char *a, char *b, size_t n)
{
    while (n--) {
        *a ^= *b;
        *b ^= *a;
        *a ^= *b;
        a++;
        b++;
    }
}

void my_memrev(char *s, size_t n)
{
    switch (n) {
    case 0:
    case 1:
        break;
    case 2:
    case 3:
        swap(s, s + n - 1, 1);
        break;
    default:
        my_memrev(s, n / 2);
        my_memrev(s + ((n + 1) / 2), n / 2);
        swap(s, s + ((n + 1) / 2), n / 2);
        break;
    }
}

void reverse(char *s)
{
    char *p;

    for (p = s; *p; p++)
        ;
    my_memrev(s, (size_t)(p - s));
}
```

Answer to Exercise 4-14, page 91

Define a macro `swap(t,x,y)` that interchanges two arguments of type `t` . (Block structure will help.)

Here are Greg's solutions for Cat 0 and Cat 1:

```
/* EXERCISE 4-14 Gregory Pietsch */

/* conditional compilation added by RJH */

#ifdef CATEGORY_0

#define swap(t,x,y) do{t z=x;x=y;y=z}while(0)

#else
#ifdef CATEGORY_1

/*
This works if I can use the assignment operator on type t.
I didn't know if I was allowed to use sizeof or not and still remain
Level 0, otherwise this one is better:
*/

#define swap(t,x,y)                          \
do {                                        \
    (unsigned char *)a=(unsigned char *)(&(x)); \
    (unsigned char *)b=(unsigned char *)(&(y)); \
    size_t i = sizeof(t);                    \
    while (i--) {                           \
        *a ^= *b;                           \
        *b ^= *a;                           \
        *a ^= *b;                           \
        a++;                                \
        b++;                                \
    }                                       \
} while (0)

#endif
#endif

/* editor's note: sizeof is first mentioned on p91, after this exercise,
 * and is not explained properly until p135, so it can be used in
 * Category 0 solutions only for exercises 6-1 onward.
```

```
 */
```

...and here is a lively entry for Category 0, from Lars, which uses token pasting to derive a name for the temporary variable:

```
/*
 * Solution to exercise 4-14 in K&R2, page 91:
 *
 *      Define a macro swap(t,x,y) that interchanges two arguments of type
t.
 *      (Block structure will help.)
 *
 * Feel free to modify and copy, if you really must, but preferably not.
 * This is just an exercise in preprocessor mechanics, not an example of
 * how it should really be used. The trickery is not worth it to save three
 * lines of code.
 *
 * To exchange the values of two variables we need a temporary variable
and
 * this one needs a name. Any name we pick, the user of the macro might
also
 * use. Thus, we use the preprocessor argument concatenation operator ##
to
 * create the name from the actual variable names in the call. This
guarantees
 * that the result won't be either of the actual arguments. In order to
 * make sure the result also does not fall into the implementation's name
 * space, we prefix the name with something safe.
 *
 * Lars Wirzenius <liw@iki.fi>
 */

#include <stdio.h>

#define swap(t, x, y) \
        do { \
                t safe ## x ## y; \
                safe ## x ## y = x; \
                x = y; \
```

```
                y = safe ## x ## y; \
        } while (0)

int main(void) {
        int ix, iy;
        double dx, dy;
        char *px, *py;

        ix = 42;
        iy = 69;
        printf("integers before swap: %d and %d\n", ix, iy);
        swap(int, ix, iy);
        printf("integers after swap: %d and %d\n", ix, iy);

        dx = 123.0;
        dy = 321.0;
        printf("doubles before swap: %g and %g\n", dx, dy);
        swap(double, dx, dy);
        printf("integers after swap: %g and %g\n", dx, dy);

        px = "hello";
        py = "world";
        printf("pointers before swap: %s and %s\n", px, py);
        swap(char *, px, py);
        printf("integers after swap: %s and %s\n", px, py);

        return 0;
}
```

...and here is yet another solution from Gregory:

```
#define swap(t,x,y)                                     \
do {                                                \
   (unsigned char *)_0=(unsigned char *)(&(x));       \
   (unsigned char *)_1=(unsigned char *)(&(y));       \
   unsigned long _2 = (unsigned long)                 \
      ((unsigned char *)(&(x)+1)                      \
       - (unsigned char *)(&(x)));                    \
   while (_2--) {                                    \
      *_0 ^= *_1;                                    \
      *_1 ^= *_0;                                    \
      *_0 ^= *_1;                                    \
      _0++;                                         \
```

```
        _1++;                                   \
    }                                           \
} while (0)
```

Answer to Exercise 5-1, page 97

As written, `getint` treats a + or - not followed by a digit as a valid representation of zero. Fix it to push such a character back on the input.

Here is Greg's solution:

```
#include <ctype.h>

int getch(void);
void ungetch(int);

/* getint:  get next integer from input into *pn */
int getint(int *pn)
{
    int c, sign, sawsign;

    while (isspace(c = getch()))   /* skip white space */
        ;
    if (!isdigit(c) && c != EOF && c != '+' && c != '-') {
        ungetch(c);    /* it's not a number */
        return 0;
    }
    sign = (c == '-') ? -1 : 1;
    if (sawsign = (c == '+' || c == '-'))
        c = getch();
    if (!isdigit(c)) {
        ungetch(c);
        if (sawsign)
            ungetch((sign == -1) ? '-' : '+');
        return 0;
    }
    for (*pn = 0; isdigit(c); c = getch())
        *pn = 10 * *pn + (c - '0');
    *pn *= sign;
    if (c != EOF)
        ungetch(c);
```

```
    return c;
}
```

Answer to Exercise 5-2, page 97

Write `getfloat` , the floating-point analog of `getint` . What type does `getfloat` return as its function value?

Here is Chris's solution:

```
/*
 * Exercise 5-2 from The C Programming Language, 2nd edition, by Kernighan
 * and Ritchie.
 *
 * "Write getfloat, the floating-point analog of getint. What type does
 * getfloat return as its function value?"
 */

/*
 * Here's the getint function, from section 5.2:
 */

#include <ctype.h>
#include <stdio.h>

int getch(void);
void ungetch(int);

/* getint:  get next integer from input into *pn */
int getint(int *pn)
{
	int c, sign;

	while (isspace(c = getch()))  /* skip white space */
		;

	if (!isdigit(c) && c != EOF && c != '+' && c != '-') {
		ungetch(c);  /* it is not a number */
		return 0;
	}
	sign = (c == '-') ? -1 : 1;
	if (c == '+' || c == '-')
		c = getch();
	for (*pn = 0; isdigit(c); c = getch())
```

```
                *pn = 10 * *pn + (c - '0');
        *pn *= sign;
        if (c != EOF)
                ungetch(c);
        return c;
}

/*
 * The getch and ungetch functions, from section 4.3, are also required.
 */

#include <stdio.h>

#define BUFSIZE 100

char buf[BUFSIZE];      /* buffer for ungetch */
int bufp = 0;           /* next free position in buf */

int getch(void)         /* get a (possibly pushed-back) character */
{
        return (bufp > 0) ? buf[--bufp] : getchar();
}

void ungetch(int c)     /* push character back on input */
{
        if (bufp >= BUFSIZE)
                printf("ungetch: too many characters\n");
        else
                buf[bufp++] = c;
}

/*
 * The getfloat function.
 *
 * Reads the next number from input, and puts it into *fp.  Returns EOF
for
 * end of file, zero if the next input is not a number, and a positive
 * value of the input contains a valid number.
 *
 * Based heavily on the getint function from K&R2.
 */

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

```c
int getfloat(float *fp)
{
	int ch;
	int sign;
	int fraction;
	int digits;

	while (isspace(ch = getch()))  /* skip white space */
		;

	if (!isdigit(ch) && ch != EOF && ch != '+'
			&& ch != '-' && ch != '.') {
		ungetch(ch);
		return 0;
	}

	sign = (ch == '-') ? -1 : 1;
	if (ch == '+' || ch == '-') {
		ch = getch();
		if (!isdigit(ch) && ch != '.') {
			if (ch == EOF) {
				return EOF;
			} else {
				ungetch(ch);
				return 0;
			}
		}
	}

	*fp = 0;
	fraction = 0;
	digits = 0;
	for ( ; isdigit(ch) || ch == '.' ; ch = getch()) {
		if (ch == '.') {
			fraction = 1;
		} else {
			if (!fraction) {
				*fp = 10 * *fp + (ch - '0');
			} else {
				*fp = *fp + ((ch - '0') / pow(10, fraction));
				fraction++;
			}
			digits++;
```

```
		}
	}

	*fp *= sign;

	if (ch == EOF) {
		return EOF;
	} else {
		ungetch(ch);
		return (digits) ? ch : 0;
	}
}

/*
 * Test module.
 */

#include <stdio.h>

int main(void)
{
	int ret;

	do {
		float f;

		fputs("Enter a number: ", stdout);
		fflush(stdout);
		ret = getfloat(&f);
		if (ret > 0) {
			printf("You entered: %f\n", f);
		}
	} while (ret > 0);

	if (ret == EOF) {
		puts("Stopped by EOF.");
	} else {
		puts("Stopped by bad input.");
	}

	return 0;
}
```

...and here is Greg's solution:

```
/* Gregory Pietsch <gkp1@flash.net> Exercise 5-2 dated 2001-01-08 */

#include <ctype.h>
#include <limits.h>

/* also uses getch and ungetch from Section 4.3 */

/* number of significant digits in a double */
#define SIG_MAX 32

/* store double in d; return next character */
int getfloat(double *d)
{
    const char point = '.';    /* localeconv->decimal_point[0]; */
    int c;
    char buf[SIG_MAX], sign, sawsign, sawe, sawesign, esign;
    double x;
    static double fac[] = {0.0, 1.0e8, 1.0e16, 1.0e24, 1.0e32};
    double dpow;
    int ndigit, nsig, nzero, olead, opoint, n;
    char *pc;
    long lo[SIG_MAX / 8 + 1], lexp;
    long *pl;

    /* skip white space */
    while (isspace(c = getch()))
        ;
    if (sawsign = (c == '-' || c == '+')) {
        sign = c;
        c = getch();
    } else
        sign = '+';
    olead = -1;
    opoint = -1;
    ndigit = 0;
    nsig = 0;
    nzero = 0;
    while (c != EOF) {
        if (c == point) {
            if (0 <= opoint)
```

```
            break;  /* already seen point */
        else
            opoint = ndigit;
    } else if (c == '0') {
        /* saw a zero */
        nzero++;
        ndigit++;
    } else if (!isdigit(c))
        break;      /* found nondigit */
    else {
        /* got a nonzero digit */
        if (olead < 0)
            olead = nzero;
        else {
            /* deliver zeros */
            for ( ; 0 < nzero && nsig < SIG_MAX; --nzero)
                buf[nsig++] = 0;
        }
        ++ndigit;
        /* deliver digit */
        if (nsig < SIG_MAX)
            buf[nsig++] = (c - '0');
    }
    c = getch();
}
if (ndigit == 0) {
    /* no digits? */
    *d = 0.0;
    if (c != EOF)
        ungetch(c);
    if (0 <= opoint) {
        /* saw point */
        ungetch(c = point);
    }
    if (sawsign) {
        /* saw sign */
        ungetch(c = sign);
    }
    return c;
}
/* skip trailing digits */
for ( ; 0 < nsig && buf[nsig - 1] == 0; --nsig)
    ;
/* compute significand */
```

```
pc = buf;
pl = &(lo[nsig >> 3]);
for (*pl = 0, n = nsig; 0 < n; --n) {
    if ((n & 7) == 0)
        /* start new sum */
        *--pl = *pc++;
    else
        *pl = *pl * 10 + *pc++;
}
for (*d = (double)(lo[0]), n = 0; ++n <= (nsig >> 3); )
    if (lo[n] != 0)
       *d += fac[n] * (double)(lo[n]);
/* fold in any explicit exponent */
lexp = 0;
if (c == 'e' || c == 'E') {
    /* we have an explicit exponent */
    sawe = c;
    c = getch();
    if (sawesign = (c == '+' || c == '-')) {
        esign = c;
        c = getch();
    } else
        esign = '+';
    if (!isdigit(c)) {
        /* ill-formed exponent */
        if (c != EOF)
            ungetch(c);
        if (sawesign)
            ungetch(c = esign);
        c = sawe;
    } else {
        /* get exponent */
        while (isdigit(c)) {
            /* get explicit exponent digits */
            if (lexp < 100000)
                lexp = lexp * 10 + (c - '0');
            /* else overflow */
            c = getch();
        }
        if (esign == '-')
            lexp = -lexp;
    }
}
if (c != EOF)
```

```
        ungetch(c);
    if (opoint < 0)
        lexp += ndigit - nsig;
    else
        lexp += opoint - olead - nsig;
    /* this is where I pray I don't lose precision */
    esign = (lexp < 0) ? '-' : '+';
    /* if anyone has a better way of handling overflow, tell me */
    if (lexp < SHRT_MIN)
        lexp = SHRT_MIN;
    if (lexp > SHRT_MAX)
        lexp = SHRT_MAX;
    if (lexp < 0)
        lexp = -lexp;
    if (lexp != 0) {
        dpow = (esign == '-') ? 0.1 : 10.0;
        while (lexp != 0) {
            /* form 10.0 to the lexp power */
            if ((lexp & 1) != 0) /* lexp is positive */
                *d *= dpow;
            lexp >>= 1;
            dpow *= dpow;
        }
    }
    /* if there was a minus sign in front, negate *d */
    if (sign == '-')
        *d = -(*d);
    return c;
}
```

Answer to Exercise 5-3, page 107

Write a pointer version of the function `strcat` that we showed in Chapter 2: `strcat(s,t)` copies the string `t` to the end of `s`.

```
/* ex 5-3, p107 */

#include <stdio.h>

void strcpy(char *s, char *t)
{
  while(*s++ = *t++);
}
```

```
void strcat(char *s, char *t)
{
  while(*s)
  {
    ++s;
  }
  strcpy(s, t);
}

int main(void)
{
  char testbuff[128];

  char *test[] =
  {
    "",
    "1",
    "12",
    "123",
    "1234"
  };

  size_t numtests = sizeof test / sizeof test[0];
  size_t thistest;
  size_t inner;

  for(thistest = 0; thistest < numtests; thistest++)
  {
    for(inner = 0; inner < numtests; inner++)
    {
      strcpy(testbuff, test[thistest]);
      strcat(testbuff, test[inner]);

      printf("[%s] + [%s] = [%s]\n", test[thistest], test[inner],
testbuff);
    }
  }

  return 0;
}
```

Give nineteen programmers a spec, and you'll get at least twenty completely different

programs. As a tiny example of this, here's a totally different solution, by Bryan Williams.

```
/*

  Exercise 5-3. Write a pointer version of the function strcat that we
showed in
              Chapter 2: strcat(s,t) copies the string t to the end of
s.

  implementation from chapter 2:

/ * strcat:  concatenate t to end of s; s must be big enough * /
void strcat(char s[], char t[])
{
  int i, j;

  i = j = 0;
  while (s[i] != '\0')  / * find end of s * /
    i++;
  while ((s[i++] = t[j++]) != '\0')  / * copy t * /
    ;
}


  Author : Bryan Williams

*/


/* strcat:  concatenate t to end of s; s must be big enough; pointer version
*/
void strcat(char *s, char *t)
{
  /* run through the destination string until we point at the terminating
'\0' */
  while('\0' != *s)
  {
    ++s;
  }

  /* now copy until we run out of string to copy */
  while('\0' != (*s = *t))
  {
```

```
    ++s;
    ++t;
  }

}

#define DRIVER        6

#if DRIVER
#include <stdio.h>

int main(void)
{
  char S1[8192] = "String One";
  char S2[8192] = "String Two";


  printf("String one is (%s)\n", S1);
  printf("String two is (%s)\n", S2);

  strcat(S1, S2);
  printf("The combined string is (%s)\n", S1);

  return 0;
}

#endif
```

Answer to Exercise 5-4, page 107

Write the function `strend(s,t)` , which returns 1 if the string `t` occurs at the end of the string `s` , and zero otherwise.

```
/*

   Exercise 5-4. Write the function strend(s,t), which returns 1 if the
string t
                occurs at the end of the string s, and zero otherwise.

   Author : Bryan Williams

*/
```

```c
int strlen(char *s) /* added by RJH; source: K&R p99 */
{
  int n;

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

int strcmp(char *s, char *t) /* added by RJH; source: K&R p106 */
{
  for(;*s == *t; s++, t++)
    if(*s == '\0')
      return 0;
  return *s - *t;
}


int strend(char *s, char *t)
{
  int Result = 0;
  int s_length = 0;
  int t_length = 0;

  /* get the lengths of the strings */
  s_length = strlen(s);
  t_length = strlen(t);

  /* check if the lengths mean that the string t could fit at the string
s */
  if(t_length <= s_length)
  {
    /* advance the s pointer to where the string t would have to start
in string s */
    s += s_length - t_length;

    /* and make the compare using strcmp */
    if(0 == strcmp(s, t))
    {
      Result = 1;
    }
  }
```

```
  return Result;
}
```

```
#include <stdio.h>


int main(void)
{
  char *s1 = "some really long string.";
  char *s2 = "ng.";
  char *s3 = "ng";

  if(strend(s1, s2))
  {
    printf("The string (%s) has (%s) at the end.\n", s1, s2);
  }
  else
  {
    printf("The string (%s) doesn't have (%s) at the end.\n", s1, s2);
  }
  if(strend(s1, s3))
  {
    printf("The string (%s) has (%s) at the end.\n", s1, s3);
  }
  else
  {
    printf("The string (%s) doesn't have (%s) at the end.\n", s1, s3);
  }

  return 0;
}
```

Answer to Exercise 5-5, page 107

Write versions of the library functions `strncpy` , `strncat` , and `strncmp` , which operate on at most the first `n` characters of their argument strings. For example, `strncpy(s,t,n)` copies at most `n` characters of `t` to `s` . Full descriptions are in Appendix B.

Note: Lars uses EXIT_FAILURE in his test code, but not in the actual solution code. As far as I can tell, then, this is a Category 0 solution.

```
/*
 * Solution to exercise 5-5 in K&R2, page 107:
 *
 *      Write versions of the library functions strncpy, strncat,
 *      and strncmp, which operate on at most the first n characters
 *      of their argument strings. For example, strncpy(s,t,n) copies
 *      at most n characters of t to s. Full descriptions are in
 *      Appendix B.
 *
 * Note that the description in the exercise is not precise. Here are
 * descriptions from Appendix B (though one should really follow the
 * descriptions in the standard):
 *
 *      char *strncpy(s,ct,n)  copy at most n characters of string ct
 *                             to s, return s. Pad with '\0's is ct
 *                             has fewer than n characters.
 *      char *strncat(s,ct,n)  concatenate at most n characters of
 *                             string ct to string s, terminate s with
 *                             '\0'; return s.
 *      int strncmp(cs,ct,n)   compare at most n characters of string
 *                             cs to string ct; return <0 if cs<ct,
 *                             0 if cs==ct, or >0 if cs>ct.
 *
 * Further note that the standard requires strncmp to compare the
 * characters using unsigned char internally.
 *
 * Implementation note: since the function names are reserved by the
 * standard, I've used the prefix `liw_'. This also allows me to check
 * the functions against the standard library versions. For each library
 * function, I've written a test function that tests a particular test
 * case. Where appropriate, the test functions use internal buffers that
 * are of size MAX_BUF; at least some of the test cases should be longer
 * to test all boundary conditions.
 *
 * Feel free to modify, copy, and use as you wish.
 *
 * Lars Wirzenius <liw@iki.fi>
 */

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

```c
#define MAX_BUF 16

char *liw_strncpy(char *s, const char *ct, size_t n) {
        char *p;

        p = s;
        for (; n > 0 && *ct != '\0'; --n)
                *p++ = *ct++;
        for (; n > 0; --n)
                *p++ = '\0';
        return s;
}

char *liw_strncat(char *s, const char *ct, size_t n) {
        char *p;

        p = s;
        while (*p != '\0')
                ++p;
        for (; n > 0 && *ct != '\0'; --n)
                *p++ = *ct++;
        *p = '\0';
        return s;
}

int liw_strncmp(const char *cs, const char *ct, size_t n) {
        while (n > 0 && *cs == *ct && *cs != '\0') {
                ++cs;
                ++ct;
                --n;
        }
        if (n == 0 || *cs == *ct)
                return 0;
        if (*(unsigned char *) cs < *(unsigned char *) ct)
                return -1;
        return 1;
}

void test_ncpy(const char *str) {
        char std_buf[MAX_BUF];
        char liw_buf[MAX_BUF];

        memset(std_buf, 0x42, sizeof(std_buf));
        strncpy(std_buf, str, sizeof(std_buf));
```

```
        memset(liw_buf, 0x42, sizeof(liw_buf));
        liw_strncpy(liw_buf, str, sizeof(liw_buf));

        if (memcmp(std_buf, liw_buf, sizeof(std_buf)) != 0) {
                fprintf(stderr, "liw_strncpy failed for <%s>\n", str);
                exit(EXIT_FAILURE);
        }
}

void test_ncat(const char *first, const char *second) {
        char std_buf[MAX_BUF];
        char liw_buf[MAX_BUF];

        memset(std_buf, 0x69, sizeof(std_buf));
        strcpy(std_buf, first);
        strncat(std_buf, second, sizeof(std_buf) - strlen(std_buf) - 1);

        memset(liw_buf, 0x69, sizeof(liw_buf));
        strcpy(liw_buf, first);
        liw_strncat(liw_buf, second, sizeof(liw_buf) - strlen(liw_buf)
- 1);

        if (memcmp(std_buf, liw_buf, sizeof(std_buf)) != 0) {
                fprintf(stderr, "liw_strncat failed, <%s> and <%s>\n",
                        first, second);
                exit(EXIT_FAILURE);
        }
}

void test_ncmp(const char *first, const char *second) {
        size_t len;
        int std_ret, liw_ret;

        if (strlen(first) < strlen(second))
                len = strlen(second);
        else
                len = strlen(first);
        std_ret = strncmp(first, second, len);
        liw_ret = liw_strncmp(first, second, len);
        if ((std_ret < 0 && liw_ret >= 0) || (std_ret > 0 && liw_ret <=
0) ||
           (std_ret == 0 && liw_ret != 0)) {
                fprintf(stderr, "liw_strncmp failed, <%s> and <%s>\n",
```

```
                        first, second);
                exit(EXIT_FAILURE);
        }
}

int main(void) {
        test_ncpy("");
        test_ncpy("a");
        test_ncpy("ab");
        test_ncpy("abcdefghijklmnopqrstuvwxyz");    /* longer than
MAX_BUF */

        test_ncat("", "a");
        test_ncat("a", "bc");
        test_ncat("ab", "cde");
        test_ncat("ab", "cdefghijklmnopqrstuvwxyz"); /* longer than
MAX_BUF */

        test_ncmp("", "");
        test_ncmp("", "a");
        test_ncmp("a", "a");
        test_ncmp("a", "ab");
        test_ncmp("abc", "ab");

        printf("All tests pass.\n");
        return 0;
}
```

Exercise 5-6, page 107

Greg supplied a fresh version of this answer (which supersedes the old answer, so I've removed it) on 29 Jan 2001.

Rewrite appropriate programs from earlier chapters and exercises with pointers instead of array indexing. Good possibilities include `getline` (Chapters 1 and 4), `atoi` , `itoa` , and their variants (Chapters 2, 3, and 4), `reverse` (Chapter 3), and `strindex` and `getop` (Chapter 4).

```
/* Gregory Pietsch ex. 5-6 dated 2001-01-29 */

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

```c
/* getline: get line into s, return length */
int getline(char *s, int lim)
{
    char *p;
    int c;

    p = s;
    while (--lim > 0 && (c = getchar()) != EOF && c != '\n')
        *p++ = c;
    if (c == '\n')
        *p++ = c;
    *p = '\0';
    return (int)(p - s);
}

/* atoi: convert s to an integer
 *
 * Here's the easy way:
 * int atoi(char *s){return (int)strtoul(s, NULL, 10);}
 * But I'll behave...
 */
int atoi(char *s)
{
    int n, sign;

    while (isspace(*s))
        s++;
    sign = (*s == '+' || *s == '-') ? ((*s++ == '+') ? 1 : -1) : 1;
    for (n = 0; isdigit(*s); s++)
        n = (n * 10) + (*s - '0');  /* note to language lawyers --
                                     * the digits are in consecutive
                                     * order in the character set
                                     * C90 5.2.1
                                     */
    return sign * n;
}

/* Shamelessly copied from my 4-12 answer

itoa() is non-standard, but defined on p.64 as having this prototype:

void itoa(int n, char s[])

Instead of this, I thought I'd use a different prototype (one I got from
```

```
the library manual of one of my compilers) since it includes all of the
above:

char *itoa(int value, char *digits, int base);

Description:  The itoa() function converts an integer value into an
ASCII string of digits.  The base argument specifies the number base for

the conversion.  The base must be a value in the range [2..36], where 2
is binary, 8 is octal, 10 is decimal, and 16 is hexadecimal.  The buffer

pointed to by digits must be large enough to hold the ASCII string of
digits plus a terminating null character.  The maximum amount of buffer
space used is the precision of an int in bits + 2 (one for the sign and
one for the terminating null).

Returns:  digits, or NULL if error.

*/

char *utoa(unsigned value, char *digits, int base)
{
    char *s, *p;

    s = "0123456789abcdefghijklmnopqrstuvwxyz"; /* don't care if s is in

                                                 * read-only memory
                                                 */
    if (base == 0)
        base = 10;
    if (digits == NULL || base < 2 || base > 36)
        return NULL;
    if (value < (unsigned) base) {
        digits[0] = s[value];
        digits[1] = '\0';
    } else {
        for (p = utoa(value / ((unsigned)base), digits, base);
             *p;
             p++);
        utoa( value % ((unsigned)base), p, base);
    }
    return digits;
}
```

```
char *itoa(int value, char *digits, int base)
{
    char *d;
    unsigned u; /* assume unsigned is big enough to hold all the
                 * unsigned values -x could possibly be -- don't
                 * know how well this assumption holds on the
                 * DeathStation 9000, so beware of nasal demons
                 */

    d = digits;
    if (base == 0)
        base = 10;
    if (digits == NULL || base < 2 || base > 36)
        return NULL;
    if (value < 0) {
        *d++ = '-';
        u = -((unsigned)value);
    } else
        u = value;
    utoa(u, d, base);
    return digits;
}

/* reverse, shamelessly copied from my 4-13 answer */

static void swap(char *a, char *b, size_t n)
{
    while (n--) {
        *a ^= *b;
        *b ^= *a;
        *a ^= *b;
        a++;
        b++;
    }
}

void my_memrev(char *s, size_t n)
{
    switch (n) {
    case 0:
    case 1:
        break;
    case 2:
```

```
    case 3:
        swap(s, s + n - 1, 1);
        break;
    default:
        my_memrev(s, n / 2);
        my_memrev(s + ((n + 1) / 2), n / 2);
        swap(s, s + ((n + 1) / 2), n / 2);
        break;
    }
}

void reverse(char *s)
{
    char *p;

    for (p = s; *p; p++)
        ;
    my_memrev(s, (size_t)(p - s));
}

/* strindex: return index of t in s, -1 if not found */

/* needed strchr(), so here it is: */

static char *strchr(char *s, int c)
{
    char ch = c;

    for ( ; *s != ch; ++s)
        if (*s == '\0')
            return NULL;
    return s;
}

int strindex(char *s, char *t)
{
    char *u, *v, *w;

    if (*t == '\0')
        return 0;
    for (u = s; (u = strchr(u, *t)) != NULL; ++u) {
        for (v = u, w = t; ; )
            if (*++w == '\0')
                return (int)(u - s);
```

```
            else if (*++v != *w)
                break;
    }
    return -1;
}

/* getop */

#define NUMBER '0'     /* from Chapter 4 */

int getop(char *s)
{
    int c;

    while ((*s = c = getch()) == ' ' || c == '\t')
        ;
    *(s + 1) = '\0';
    if (!isdigit(c) && c != '.')
        return c;      /* not a number */
    if (isdigit(c))    /* collect integer part */
        while (isdigit(*++s = c = getch()))
            ;
    if (c == '.')      /* collect fraction part */
        while (isdigit(*++s = c = getch()))
            ;
    *++s = '\0';
    if (c != EOF)
        ungetch(c);
    return NUMBER;
}

/* Is there any more? */
```

Answer to Exercise 5-7, page 110

Rewrite `readlines` to store lines in an array supplied by `main` , rather than calling `alloc` to maintain storage. How much faster is the program?

```
/* K&R Exercise 5-7 */
/* Steven Huang */
```

```c
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <time.h>

#define TRUE    1
#define FALSE   0

#define MAXLINES 5000      /* maximum number of lines */
#define MAXLEN   1000      /* maximum length of a line */
char *lineptr[MAXLINES];
char lines[MAXLINES][MAXLEN];

/* K&R2 p29 */
int getline(char s[], int lim)
{
  int c, i;

  for (i = 0; i < lim - 1 && (c = getchar()) != EOF && c != '\n'; i++)
    s[i] = c;
  if (c == '\n') {
    s[i++] = c;
  }
  s[i] = '\0';
  return i;
}

/* K&R2 p109 */
int readlines(char *lineptr[], int maxlines)
{
  int len, nlines;
  char *p, line[MAXLEN];

  nlines = 0;
  while ((len = getline(line, MAXLEN)) > 0)
    if (nlines >= maxlines || (p = malloc(len)) == NULL)
      return -1;
    else {
      line[len - 1] = '\0';  /* delete the newline */
      strcpy(p, line);
      lineptr[nlines++] = p;
    }
  return nlines;
}
```

```
int readlines2(char lines[][MAXLEN], int maxlines)
{
  int len, nlines;

  nlines = 0;
  while ((len = getline(lines[nlines], MAXLEN)) > 0)
    if (nlines >= maxlines)
      return -1;
    else
      lines[nlines++][len - 1] = '\0';  /* delete the newline */
  return nlines;
}

int main(int argc, char *argv[])
{
  /* read things into cache, to be fair. */
  readlines2(lines, MAXLINES);

  if (argc > 1 && *argv[1] == '2') {
    puts("readlines2()");
    readlines2(lines, MAXLINES);
  } else {
    puts("readlines()");
    readlines(lineptr, MAXLINES);
  }

  return 0;
}
```

Steven writes: "Unfortunately, the follow-up question here on which version is faster is difficult to determine on my machine, because the difference is very small. I can call `malloc()` one million times in under a second - this suggests that the conventional wisdom that `malloc()` is slow and should be avoided may need some more adjustment."

[Editor's note: That's probably because `malloc` is actually taking memory requests to the system as infrequently as possible, so that most of the calls invoke little more than pointer arithmetic. This suggests that the conventional wisdom may be based on real world programs, rather than artificial "how many `mallocs` per second can I do" benchmarks. :-)]

[This space reserved for Steven's right of reply!]

Exercise 5-8

There is no error-checking in `day_of_year` or `month_day`. Remedy this defect.

```
/*
 * A solution to exercise 5-8 in K&R2, page 112:
 *
 *      There is no error checking in day_of_year or month_day. Remedy
 *      this defect.
 *
 * The error to check for is invalid argument values. That is simple, what's
 * hard is deciding what to do in case of error. In the real world, I would
 * use the assert macro from assert.h, but in this solution I take the
 * approach of returning -1 instead. This is more work for the caller,
of
 * course.
 *
 * I have selected the year 1752 as the lowest allowed year, because that
 * is when Great Britain switched to the Gregorian calendar, and the leap
 * year validation is valid only for the Gregorian calendar.
 *
 * Lars Wirzenius <liw@iki.fi>
 */

#include <stdio.h>

static char daytab[2][13] =  {
        {0, 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31},
        {0, 31, 29, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31},
};

/* day_of_year: set day of year from month & day */
int day_of_year(int year, int month, int day)
{
        int i, leap;

        if (year < 1752 || month < 1 || month > 12 || day < 1)
                return -1;

        leap = (year%4 == 0 && year%100 != 0) || year%400 == 0;
```

```
        if (day > daytab[leap][month])
                return -1;

        for (i = 1; i < month; i++)
                day += daytab[leap][i];
        return day;
}

/* month_day: set month, day from day of year */
int month_day(int year, int yearday, int *pmonth, int *pday)
{
        int i, leap;

        if (year < 1752 || yearday < 1)
                return -1;

        leap = (year%4 == 0 && year%100 != 0) || year%400 == 0;
        if ((leap && yearday > 366) || (!leap && yearday > 365))
                return -1;

        for (i = 1; yearday > daytab[leap][i]; i++)
                yearday -= daytab[leap][i];
        *pmonth = i;
        *pday = yearday;

        return 0;
}


/* main: test day_of_year and month_day */
int main(void)
{
        int year, month, day, yearday;

        for (year = 1970; year <= 2000; ++year) {
                for (yearday = 1; yearday < 366; ++yearday) {
                        if (month_day(year, yearday, &month, &day) == -1)
{
                                printf("month_day failed: %d %d\n",
                                        year, yearday);
                        } else if (day_of_year(year, month, day) !=
yearday) {
                                printf("bad result: %d %d\n", year,
yearday);
```

```
                                printf("month = %d, day = %d\n", month,
day);
                        }
                }
        }

        return 0;
}
```

Exercise 5-9, page 114

Rewrite the routines `day_of_year` and `month_day` with pointers instead of indexing.

Here's Lars's solution: @br @br

```
/*
 * A solution to exercise 5-9 in K&R2, page 114:
 *
 *      Rewrite the routines day_of_year and month_day with pointers
 *      instead of indexing.
 *
 * Lars Wirzenius <liw@iki.fi>
 */

#include <stdio.h>

static char daytab[2][13] =  {
        {0, 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31},
        {0, 31, 29, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31},
};

/* original versions, for comparison purposes */

int day_of_year(int year, int month, int day)
{
        int i, leap;

        leap = (year%4 == 0 && year%100 != 0) || year%400 == 0;
        for (i = 1; i < month; i++)
                day += daytab[leap][i];
        return day;
}
```

```c
void month_day(int year, int yearday, int *pmonth, int *pday)
{
        int i, leap;

        leap = (year%4 == 0 && year%100 != 0) || year%400 == 0;
        for (i = 1; yearday > daytab[leap][i]; i++)
                yearday -= daytab[leap][i];
        *pmonth = i;
        *pday = yearday;
}


/* pointer versions */

int day_of_year_pointer(int year, int month, int day)
{
        int i, leap;
        char *p;

        leap = (year%4 == 0 && year%100 != 0) || year%400 == 0;

        /* Set `p' to point at first month in the correct row. */
        p = &daytab[leap][1];

        /* Move `p' along the row, to each successive month. */
        for (i = 1; i < month; i++) {
                day += *p;
                ++p;
        }
        return day;
}

void month_day_pointer(int year, int yearday, int *pmonth, int *pday)
{
        int i, leap;
        char *p;

        leap = (year%4 == 0 && year%100 != 0) || year%400 == 0;
        p = &daytab[leap][1];
        for (i = 1; yearday > *p; i++) {
                yearday -= *p;
                ++p;
        }
        *pmonth = i;
```

```
        *pday = yearday;
}


int main(void)
{
        int year, month, day, yearday;

        year = 2000;
        month = 3;
        day = 1;
        printf("The date is: %d-%02d-%02d\n", year, month, day);
        printf("day_of_year: %d\n", day_of_year(year, month, day));
        printf("day_of_year_pointer: %d\n",
                day_of_year_pointer(year, month, day));


        yearday = 61;  /* 2000-03-01 */
        month_day(year, yearday, &month, &day);
        printf("Yearday is %d\n", yearday);
        printf("month_day: %d %d\n", month, day);
        month_day_pointer(year, yearday, &month, &day);
        printf("month_day_pointer: %d %d\n", month, day);

        return 0;
}
```

And here's Greg's: @br @br

```
/* Gregory Pietsch - gkp1@flash.net */

/* Given the problem, I thought that this would be a better
 * description of daytab.
 */
static int *daytab = {
   0,
   31,
   31+28,
   31+28+31,
   31+28+31+30,
   31+28+31+30+31,
   31+28+31+30+31+30,
   31+28+31+30+31+30+31,
```

```
    31+28+31+30+31+30+31+31,
    31+28+31+30+31+30+31+31+30,
    31+28+31+30+31+30+31+31+30+31,
    31+28+31+30+31+30+31+31+30+31+30,
    0,
    31,
    31+29,
    31+29+31,
    31+29+31+30,
    31+29+31+30+31,
    31+29+31+30+31+30,
    31+29+31+30+31+30+31,
    31+29+31+30+31+30+31+31,
    31+29+31+30+31+30+31+31+30,
    31+29+31+30+31+30+31+31+30+31,
    31+29+31+30+31+30+31+31+30+31+30,
};

/* is it a leap year?  (assume it's my calendar, the Gregorian) */
int leap(int year)
{
    return ((year % 4) == 0)
           && (((year % 100) != 0)
               || (year % 400) == 0)));
}

/* day_of_year:  set day of year from month & day */
int day_of_year(int year, int month, int day)
{
    return *(daytab + ((month - 1) + (leap(year) * 12))) + day;
}

/* month_day: set month, day from day of year */
void month_day(int year, int yearday, int *pmonth, int *pday)
{
    int m, ly;

    ly = leap(year);
    if (yearday < 1 || yearday > (365 + ly))
        return; /* no real error checking */
    m = leap(year) ? 23 : 11;
    while (*(daytab + m) > yearday)
        m--;
    if (pmonth)
```

```
        *pmonth = (m % 12) + 1;
    if (pday)
        *pday = yearday - (*(daytab + m));
}
```

Answer to Exercise 8-6, page 189

The standard library function `calloc(n,size)` returns a pointer to n objects of size `size` , with the storage initialized to zero. Write `calloc` , by calling `malloc` or by modifying it.

```
/*
    Exercise 8.6. The standard library function calloc(n, size) returns
a pointer to n objects
                of size size, with the storage initialised to zero. Write
calloc, by calling
                malloc or by modifying it.

    Author: Bryan Williams

*/

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

/*
  Decided to re-use malloc for this because :
        1) If the implementation of malloc and the memory management layer
changes, this will be ok.
        2) Code re-use is great.

*/
void *mycalloc(size_t nmemb, size_t size)
{
  void *Result = NULL;

  /* use malloc to get the memory */
  Result = malloc(nmemb * size);

  /* and clear the memory on successful allocation */
  if(NULL != Result)
  {
    memset(Result, 0x00, nmemb * size);
  }
```

```
  /* and return the result */
  return Result;
}

/* simple test driver, by RJH */

#include <stdio.h>

int main(void)
{
  int *p = NULL;
  int i = 0;

  p = mycalloc(100, sizeof *p);
  if(NULL == p)
  {
    printf("mycalloc returned NULL.\n");
  }
  else
  {
    for(i = 0; i < 100; i++)
    {
      printf("%08X ", p[i]);
      if(i % 8 == 7)
      {
         printf("\n");
      }
    }
    printf("\n");
    free(p);
  }

  return 0;
}
```

Answer to Exercise 5-10, page 118

Write the program `expr` , which evaluates a reverse Polish expression from the command line, where each operator or operand is a separate argument. For example, `expr 2 3 4 + *`
evaluates 2 X (3 + 4).

Note: Lars uses EXIT_FAILURE on error. As far as I can tell, this is the only thing which makes this a Category 1, rather than Category 0, solution.

```c
/*
 * Solution to exercise 5-10 in K&R2:
 *
 *      Write the program expr, which evaluates a reverse Polish
expression
 *      from the command line, where each operator or operand is a separate
 *      argument. For example,
 *
 *              expr 2 3 4 + *
 *
 *      evaluates 2*(3+4).
 *
 * This is very similar to the program in 4.3 (and should ideally have
been
 * a modification of that).
 *
 * Feel free to modify and copy freely.
 *
 * Lars Wirzenius <liw@iki.fi>
 */

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

#define STACK_SIZE 1024

double stack[STACK_SIZE];
int stack_height = 0;

void panic(const char *msg) {
        fprintf(stderr, "%s\n", msg);
        exit(EXIT_FAILURE);
}

void push(double value) {
        if (stack_height == STACK_SIZE)
                panic("stack is too high!");
        stack[stack_height] = value;
        ++stack_height;
}

double pop(void) {
```

```
        if (stack_height == 0)
                panic("stack is empty!");
        return stack[--stack_height];
}

int main(int argc, char **argv) {
        int i;
        double value;

        for (i = 1; i < argc; ++i) {
                switch (argv[i][0]) {
                case '\0':
                        panic("empty command line argument");
                        break;
                case '0':
                case '1':
                case '2':
                case '3':
                case '4':
                case '5':
                case '6':
                case '7':
                case '8':
                case '9':
                        push(atof(argv[i]));
                        break;
                case '+':
                        push(pop() + pop());
                        break;
                case '-':
                        value = pop();
                        push(pop() - value);
                        break;
                case '*':
                        push(pop() * pop());
                        break;
                case '/':
                        value = pop();
                        push(pop() / value);
                        break;
                default:
                        panic("unknown operator");
                        break;
                }
```

```
        }

        printf("%g\n", pop());
        return 0;
}
```

Answer to Exercise 5-11, page 118

Modify the programs `entab` and `detab` (written as exercises in Chapter 1) to accept a list of tab stops as arguments. Use the default tab settings if there are no arguments.

Here's detab...

```
/*************************************************************************
********

detab.c - Source code for the detab command

AUTHOR: Gregory Pietsch

DESCRIPTION:

detab - expand tabs into spaces

*************************************************************************
*******/

/* include files */
#include <stdio.h>
#include <string.h>

/* macros */
#define NO_ARG        0
#define REQUIRED_ARG   1
#define OPTIONAL_ARG   2

/* types */

/* GETOPT_LONG_OPTION_T: The type of long option */
typedef struct GETOPT_LONG_OPTION_T {
   char *name;        /* the name of the long option */
   int has_arg;       /* one of the above macros */
   int *flag;        /* determines if getopt_long() returns a
                     * value for a long option; if it is
```

```
                    * non-NULL, 0 is returned as a function
                    * value and the value of val is stored in
                    * the area pointed to by flag.  Otherwise,
                    * val is returned. */
    int val;         /* determines the value to return if flag is
                    * NULL. */
} GETOPT_LONG_OPTION_T;

typedef enum GETOPT_ORDERING_T {
    PERMUTE,
    RETURN_IN_ORDER,
    REQUIRE_ORDER
} GETOPT_ORDERING_T;

/* globally-defined variables */
char *optarg = NULL;
int optind = 0;
int opterr = 1;
int optopt = '?';

/* statically-defined variables */

static char *program_name;
 /* if nonzero, it means tab every x characters */
static unsigned long tab_every = 8;
 /* -i: only handle initial tabs/spaces */
static int flag_initial = 0;
 /* expand tabs into spaces */
static int flag_expand = 1;
static unsigned long *tab_stop_list = NULL;
static size_t num_tab_stops = 0;
static size_t num_tab_stops_allocked = 0;
static int show_help = 0;
static int show_version = 0;
static char *shortopts = "it:";
static GETOPT_LONG_OPTION_T longopts[] =
{
    {"initial", NO_ARG, NULL, 'i'},
    {"tabs", REQUIRED_ARG, NULL, 't'},

    {"help", NO_ARG, &show_help, 1},
    {"version", NO_ARG, &show_version, 1},
    {NULL, 0, 0, 0}
};
```

```
/* functions */

/* reverse_argv_elements:  reverses num elements starting at argv */
static void reverse_argv_elements(char **argv, int num)
{
    int i;
    char *tmp;

    for (i = 0; i < (num >> 1); i++) {
        tmp = argv[i];
        argv[i] = argv[num - i - 1];
        argv[num - i - 1] = tmp;
    }
}

/* permute: swap two blocks of argv-elements given their lengths */
static void permute(char **argv, int len1, int len2)
{
    reverse_argv_elements(argv, len1);
    reverse_argv_elements(argv, len1 + len2);
    reverse_argv_elements(argv, len2);
}

/* is_option: is this argv-element an option or the end of the option
list? */
static int is_option(char *argv_element, int only)
{
    return ((argv_element == NULL)
            || (argv_element[0] == '-')
            || (only && argv_element[0] == '+'));
}

/* getopt_internal:  the function that does all the dirty work */
static int getopt_internal(int argc, char **argv, char *shortopts,
                GETOPT_LONG_OPTION_T * longopts, int *longind, int
only)
{
    GETOPT_ORDERING_T ordering = PERMUTE;
    static size_t optwhere = 0;
    size_t permute_from = 0;
    int num_nonopts = 0;
    int optindex = 0;
    size_t match_chars = 0;
```

```
    char *possible_arg = NULL;
    int longopt_match = -1;
    int has_arg = -1;
    char *cp;
    int arg_next = 0;

    /* first, deal with silly parameters and easy stuff */
    if (argc == 0 || argv == NULL || (shortopts == NULL && longopts ==
NULL))
        return (optopt = '?');
    if (optind >= argc || argv[optind] == NULL)
        return EOF;
    if (strcmp(argv[optind], "--") == 0) {
        optind++;
        return EOF;
    }
    /* if this is our first time through */
    if (optind == 0)
        optind = optwhere = 1;

    /* define ordering */
    if (shortopts != NULL && (*shortopts == '-' || *shortopts == '+'))
{
        ordering = (*shortopts == '-') ? RETURN_IN_ORDER :
REQUIRE_ORDER;
        shortopts++;
    }
    else
        ordering = (getenv("POSIXLY_CORRECT") != NULL) ? REQUIRE_ORDER :
            PERMUTE;

    /*
     * based on ordering, find our next option, if we're at the
beginning of
     * one
     */
    if (optwhere == 1) {
        switch (ordering) {
        case PERMUTE:
            permute_from = optind;
            num_nonopts = 0;
            while (!is_option(argv[optind], only)) {
                optind++;
                num_nonopts++;
```

```
            }
            if (argv[optind] == NULL) {
                /* no more options */
                optind = permute_from;
                return EOF;
            } else if (strcmp(argv[optind], "--") == 0) {
                /* no more options, but have to get `--' out of the way
*/
                permute(argv + permute_from, num_nonopts, 1);
                optind = permute_from + 1;
                return EOF;
            }
            break;
        case RETURN_IN_ORDER:
            if (!is_option(argv[optind], only)) {
                optarg = argv[optind++];
                return (optopt = 1);
            }
            break;
        case REQUIRE_ORDER:
            if (!is_option(argv[optind], only))
                return EOF;
            break;
        }
    }
    /* we've got an option, so parse it */

    /* first, is it a long option? */
    if (longopts != NULL
        && (memcmp(argv[optind], "--", 2) == 0
            || (only && argv[optind][0] == '+'))
        && optwhere == 1) {
        /* handle long options */
        if (memcmp(argv[optind], "--", 2) == 0)
            optwhere = 2;
        longopt_match = -1;
        possible_arg = strchr(argv[optind] + optwhere, '=');
        if (possible_arg == NULL) {
            /* no =, so next argv might be arg */
            match_chars = strlen(argv[optind]);
            possible_arg = argv[optind] + match_chars;
            match_chars = match_chars - optwhere;
        }
        else
```

```
            match_chars = (possible_arg - argv[optind]) - optwhere;
        for (optindex = 0; longopts[optindex].name != NULL; optindex++)
{
            if (memcmp(argv[optind] + optwhere,
                       longopts[optindex].name,
                       match_chars) == 0) {
                /* do we have an exact match? */
                if (match_chars == (int)
(strlen(longopts[optindex].name))) {
                    longopt_match = optindex;
                    break;
                }
                /* do any characters match? */
                else {
                    if (longopt_match < 0)
                        longopt_match = optindex;
                    else {
                        /* we have ambiguous options */
                        if (opterr)
                            fprintf(stderr, "%s: option `%s' is
ambiguous "
                                    "(could be `--%s' or `--%s')\n",
                                    argv[0],
                                    argv[optind],
                                    longopts[longopt_match].name,
                                    longopts[optindex].name);
                        return (optopt = '?');
                    }
                }
            }
        }
        if (longopt_match >= 0)
            has_arg = longopts[longopt_match].has_arg;
    }
    /* if we didn't find a long option, is it a short option? */
    if (longopt_match < 0 && shortopts != NULL) {
        cp = strchr(shortopts, argv[optind][optwhere]);
        if (cp == NULL) {
            /* couldn't find option in shortopts */
            if (opterr)
                fprintf(stderr,
                        "%s: invalid option -- `-%c'\n",
                        argv[0],
                        argv[optind][optwhere]);
```

```
            optwhere++;
            if (argv[optind][optwhere] == '\0') {
                optind++;
                optwhere = 1;
            }
            return (optopt = '?');
        }
        has_arg = ((cp[1] == ':')
                 ? ((cp[2] == ':') ? OPTIONAL_ARG : REQUIRED_ARG)
                 : NO_ARG);
        possible_arg = argv[optind] + optwhere + 1;
        optopt = *cp;
    }
    /* get argument and reset optwhere */
    arg_next = 0;
    switch (has_arg) {
    case OPTIONAL_ARG:
        if (*possible_arg == '=')
            possible_arg++;
        if (*possible_arg != '\0') {
            optarg = possible_arg;
            optwhere = 1;
        }
        else
            optarg = NULL;
        break;
    case REQUIRED_ARG:
        if (*possible_arg == '=')
            possible_arg++;
        if (*possible_arg != '\0') {
            optarg = possible_arg;
            optwhere = 1;
        }
        else if (optind + 1 >= argc) {
            if (opterr) {
                fprintf(stderr, "%s: argument required for option `",
                       argv[0]);
                if (longopt_match >= 0)
                    fprintf(stderr, "--%s'\n",
longopts[longopt_match].name);
                else
                    fprintf(stderr, "-%c'\n", *cp);
            }
            optind++;
```

```
            return (optopt = ':');
        }
        else {
            optarg = argv[optind + 1];
            arg_next = 1;
            optwhere = 1;
        }
        break;
    case NO_ARG:
        if (longopt_match < 0) {
            optwhere++;
            if (argv[optind][optwhere] == '\0')
                optwhere = 1;
        }
        else
            optwhere = 1;
        optarg = NULL;
        break;
    }

    /* do we have to permute or otherwise modify optind? */
    if (ordering == PERMUTE && optwhere == 1 && num_nonopts != 0) {
        permute(argv + permute_from, num_nonopts, 1 + arg_next);
        optind = permute_from + 1 + arg_next;
    }
    else if (optwhere == 1)
        optind = optind + 1 + arg_next;

    /* finally return */
    if (longopt_match >= 0) {
        if (longind != NULL)
            *longind = longopt_match;
        if (longopts[longopt_match].flag != NULL) {
            *(longopts[longopt_match].flag) =
longopts[longopt_match].val;
            return 0;
        }
        else
            return longopts[longopt_match].val;
    }
    else
        return optopt;
}
```

```
int getopt_long(int argc, char **argv, char *shortopts,
               GETOPT_LONG_OPTION_T * longopts, int *longind)
{
    return getopt_internal(argc, argv, shortopts, longopts, longind, 0);
}

void help(void)
{
    puts( "OPTIONS" );
    puts( "" );
    puts( "-i, --initial   When shrinking, make"
         " initial spaces/tabs on a line tabs" );
    puts( "              and expand every other"
         " tab on the line into spaces." );
    puts( "-t=tablist,    "
         "Specify list of tab stops.  "
         "Default is every 8 characters." );
    puts( "--tabs=tablist, "
         "The parameter tablist is a list"
         " of tab stops separated by" );
    puts( "-tablist       "
         "commas; if no commas are present,"
         " the program will put a" );
    puts( "              "
         "tab stop every x places, "
         "with x being the number in the" );
    puts( "              parameter." );
    puts( "" );
    puts( "--help         Print usage message"
         " and exit successfully." );
    puts( "" );
    puts( "--version      Print version "
         "information and exit successfully." );
}

void version(void)
{
    puts( "detab - expand tabs into spaces" );
    puts( "Version 1.0" );
    puts( "Written by Gregory Pietsch" );
}

/* allocate memory, die on error */
void *xmalloc(size_t n)
```

```
{
    void *p = malloc(n);

    if (p == NULL) {
        fprintf(stderr, "%s: out of memory\n", program_name);
        exit(EXIT_FAILURE);
    }
    return p;
}

/* reallocate memory, die on error */
void *xrealloc(void *p, size_t n)
{
    void *s;

    if (n == 0) {
        if (p != NULL)
            free(p);
        return NULL;
    }
    if (p == NULL)
        return xmalloc(n);
    s = realloc(p, n);
    if (s == NULL) {
        fprintf(stderr, "%s: out of memory\n", program_name);
        exit(EXIT_FAILURE);
    }
    return s;
}

/* Determine the location of the first character in the string s1
 * that is not a character in s2.  The terminating null is not
 * considered part of the string.
 */
char *xstrcpbrk(char *s1, char *s2)
{
    char *sc1;
    char *sc2;

    for (sc1 = s1; *sc1 != '\0'; sc1++)
        for (sc2 = s2;; sc2++)
            if (*sc2 == '\0')
                return sc1;
            else if (*sc1 == *sc2)
```

```
            break;
    return NULL;             /* terminating nulls match */
}

/* compare function for qsort() */
int ul_cmp(const void *a, const void *b)
{
    unsigned long *ula = (unsigned long *) a;
    unsigned long *ulb = (unsigned long *) b;

    return (*ula < *ulb) ? -1 : (*ula > *ulb);
}

/* handle a tab stop list -- assumes param isn't NULL */
void handle_tab_stops(char *s)
{
    char *p;
    unsigned long ul;
    size_t len = strlen(s);

    if (xstrcpbrk(s, "0123456789,") != NULL) {
        /* funny param */
        fprintf(stderr, "%s: invalid parameter\n", program_name);
        exit(EXIT_FAILURE);
    }
    if (strchr(s, ',') == NULL) {
        tab_every = strtoul(s, NULL, 10);
        if (tab_every == 0)
            tab_every = 8;
    }
    else {
        tab_stop_list = xrealloc(tab_stop_list,
             (num_tab_stops_allocked += len) * (sizeof(unsigned
long)));
        for (p = s; (p = strtok(p, ",")) != NULL; p = NULL) {
            ul = strtoul(p, NULL, 10);
            tab_stop_list[num_tab_stops++] = ul;
        }
        qsort(tab_stop_list, num_tab_stops, sizeof(unsigned long),
             ul_cmp);
    }
}

void parse_args(int argc, char **argv)
```

```
{
    int opt;

    do {
        switch ((opt = getopt_long(argc, argv, shortopts, longopts,
NULL))) {
        case 'i':             /* initial */
            flag_initial = 1;
            break;
        case 't':             /* tab stops */
            handle_tab_stops(optarg);
            break;
        case '?':             /* invalid option */
            fprintf(stderr,"For help, type:\n\t%s --help\n",
program_name);
            exit(EXIT_FAILURE);
        case 1:
        case 0:
            if (show_help || show_version) {
                if (show_help)
                    help();
                if (show_version)
                    version();
                exit(EXIT_SUCCESS);
            }
            break;
        default:
            break;
        }
    } while (opt != EOF);
}

/* output exactly n spaces */
void output_spaces(size_t n)
{
    int x = n;               /* assume n is small */

    printf("%*s", x, "");
}

/* get next highest tab stop */
unsigned long get_next_tab(unsigned long x)
{
    size_t i;
```

```
    if (tab_stop_list == NULL) {
        /* use tab_every */
        x += (tab_every - (x % tab_every));
        return x;
    }
    else {
        for (i = 0; i < num_tab_stops && tab_stop_list[i] <= x; i++);
        return (i >= num_tab_stops) ? 0 : tab_stop_list[i];
    }
}

/* the function that does the dirty work */
void tab(FILE * f)
{
    unsigned long linelength = 0;
    int c;
    int in_initials = 1;
    size_t num_spaces = 0;
    unsigned long next_tab;

    while ((c = getc(f)) != EOF) {
        if (c != ' ' && c != '\t' && num_spaces > 0) {
            /* output spaces and possible tabs */
            if (flag_expand
                || (flag_initial && !in_initials)
                || num_spaces == 1) {
                /* output spaces anyway */
                output_spaces(num_spaces);
                linelength += num_spaces;
                num_spaces = 0;
            }
            else
                while (num_spaces != 0) {
                    next_tab = get_next_tab(linelength);
                    if (next_tab > 0 && next_tab <= linelength +
num_spaces) {
                        /* output a tab */
                        putc('\t', stdout);
                        num_spaces -= (next_tab - linelength);
                        linelength = next_tab;
                    }
                    else {
                        /* output spaces */
```

```
                    output_spaces(num_spaces);
                    linelength += num_spaces;
                    num_spaces = 0;
                }
            }
        }
        switch (c) {
        case ' ':             /* space */
            num_spaces++;
            break;
        case '\b':            /* backspace */
            /* preserve backspaces in output; decrement length for
tabbing
             * purposes
             */
            putc(c, stdout);
            if (linelength > 0)
                linelength--;
            break;
        case '\n':            /* newline */
            putc(c, stdout);
            in_initials = 1;
            linelength = 0;
            break;
        case '\t':            /* tab */
            next_tab = get_next_tab(linelength + num_spaces);
            if (next_tab == 0) {
                while ((next_tab = get_next_tab(linelength)) != 0) {
                    /* output tabs */
                    putc('\t', stdout);
                    num_spaces -= (next_tab - linelength);
                    linelength = next_tab;
                }
                /* output spaces */
                output_spaces(num_spaces);
                num_spaces = 0;
                putc('\t', stdout);
                linelength += num_spaces + 1;
            }
            else
                num_spaces = next_tab - linelength;
            break;
        default:
            putc(c, stdout);
```

```
            in_initials = 0;
            linelength++;
            break;
        }
    }
}

int main(int argc, char **argv)
{
    int i;
    FILE *fp;
    char *allocked_argvs = xmalloc(argc + 1);
    char **new_argv = xmalloc((argc + 1) * sizeof(char *));
    char *p;

    program_name = argv[0];
    memset(allocked_argvs, 0, argc + 1);
    for (i = 0; i < argc; i++) {
        p = argv[i];
        if (isdigit(p[1])) {
            new_argv[i] = xmalloc(strlen(p) + 2);
            sprintf(new_argv[i], "-t%s", p + 1);
            allocked_argvs[i] = 1;
        }
        else
            new_argv[i] = p;
    }
    new_argv[argc] = NULL;
    parse_args(argc, new_argv);
    if (optind == argc)
        tab(stdin);
    else {
        for (i = optind; i < argc; i++) {
            if (strcmp(argv[i], "-") == 0)
                fp = stdin;
            else {
                fp = fopen(argv[i], "r");
                if (fp == NULL) {
                    fprintf(stderr, "%s: can't open %s\n",
                            argv[0], argv[i]);
                    abort();
                }
            }
            tab(fp);
```

```
            if (fp != stdin)
                fclose(fp);
        }
    }
    /* free everything we can */
    for (i = 0; i < argc; i++)
        if (allocked_argvs[i])
            free(new_argv[i]);
    free(allocked_argvs);
    if (tab_stop_list != NULL)
        free(tab_stop_list);
    return EXIT_SUCCESS;
}

/* END OF FILE detab.c */
```

Here's entab...

```
/*****************************************************************
********

entab.c - Source code for the detab command

AUTHOR: Gregory Pietsch

DESCRIPTION:

entab - shrinks spaces into tabs

*****************************************************************
*******/

/* include files */
#include <stdio.h>
#include <string.h>

/* macros */
#define NO_ARG        0
#define REQUIRED_ARG   1
#define OPTIONAL_ARG   2

/* types */

/* GETOPT_LONG_OPTION_T: The type of long option */
```

```
typedef struct GETOPT_LONG_OPTION_T {
   char *name;       /* the name of the long option */
   int has_arg;      /* one of the above macros */
   int *flag;        /* determines if getopt_long() returns a
                     * value for a long option; if it is
                     * non-NULL, 0 is returned as a function
                     * value and the value of val is stored in
                     * the area pointed to by flag.  Otherwise,
                     * val is returned. */
   int val;          /* determines the value to return if flag is
                     * NULL. */
} GETOPT_LONG_OPTION_T;

typedef enum GETOPT_ORDERING_T {
   PERMUTE,
   RETURN_IN_ORDER,
   REQUIRE_ORDER
} GETOPT_ORDERING_T;

/* globally-defined variables */
char *optarg = NULL;
int optind = 0;
int opterr = 1;
int optopt = '?';

/* statically-defined variables */

static char *program_name;
 /* if nonzero, it means tab every x characters */
static unsigned long tab_every = 8;
 /* -i: only handle initial tabs/spaces */
static int flag_initial = 0;
 /* don't expand tabs into spaces */
static int flag_expand = 0;
static unsigned long *tab_stop_list = NULL;
static size_t num_tab_stops = 0;
static size_t num_tab_stops_allocked = 0;
static int show_help = 0;
static int show_version = 0;
static char *shortopts = "it:";
static GETOPT_LONG_OPTION_T longopts[] =
{
   {"initial", NO_ARG, NULL, 'i'},
   {"tabs", REQUIRED_ARG, NULL, 't'},
```

```
    {"help", NO_ARG, &show_help, 1},
    {"version", NO_ARG, &show_version, 1},
    {NULL, 0, 0, 0}
};

/* functions */

/* reverse_argv_elements:  reverses num elements starting at argv */
static void reverse_argv_elements(char **argv, int num)
{
    int i;
    char *tmp;

    for (i = 0; i < (num >> 1); i++) {
        tmp = argv[i];
        argv[i] = argv[num - i - 1];
        argv[num - i - 1] = tmp;
    }
}

/* permute: swap two blocks of argv-elements given their lengths */
static void permute(char **argv, int len1, int len2)
{
    reverse_argv_elements(argv, len1);
    reverse_argv_elements(argv, len1 + len2);
    reverse_argv_elements(argv, len2);
}

/* is_option: is this argv-element an option or the end of the option
list? */
static int is_option(char *argv_element, int only)
{
    return ((argv_element == NULL)
           || (argv_element[0] == '-')
           || (only && argv_element[0] == '+'));
}

/* getopt_internal:  the function that does all the dirty work */
static int getopt_internal(int argc, char **argv, char *shortopts,
               GETOPT_LONG_OPTION_T * longopts, int *longind, int
only)
{
    GETOPT_ORDERING_T ordering = PERMUTE;
```

```
    static size_t optwhere = 0;
    size_t permute_from = 0;
    int num_nonopts = 0;
    int optindex = 0;
    size_t match_chars = 0;
    char *possible_arg = NULL;
    int longopt_match = -1;
    int has_arg = -1;
    char *cp;
    int arg_next = 0;

    /* first, deal with silly parameters and easy stuff */
    if (argc == 0 || argv == NULL || (shortopts == NULL && longopts ==
NULL))
        return (optopt = '?');
    if (optind >= argc || argv[optind] == NULL)
        return EOF;
    if (strcmp(argv[optind], "--") == 0) {
        optind++;
        return EOF;
    }
    /* if this is our first time through */
    if (optind == 0)
        optind = optwhere = 1;

    /* define ordering */
    if (shortopts != NULL && (*shortopts == '-' || *shortopts == '+'))
{
        ordering = (*shortopts == '-') ? RETURN_IN_ORDER :
REQUIRE_ORDER;
        shortopts++;
    }
    else
        ordering = (getenv("POSIXLY_CORRECT") != NULL) ? REQUIRE_ORDER :
            PERMUTE;

    /*
     * based on ordering, find our next option, if we're at the
beginning of
     * one
     */
    if (optwhere == 1) {
        switch (ordering) {
        case PERMUTE:
```

```
            permute_from = optind;
            num_nonopts = 0;
            while (!is_option(argv[optind], only)) {
               optind++;
               num_nonopts++;
            }
            if (argv[optind] == NULL) {
               /* no more options */
               optind = permute_from;
               return EOF;
            } else if (strcmp(argv[optind], "--") == 0) {
               /* no more options, but have to get `--' out of the way
*/
               permute(argv + permute_from, num_nonopts, 1);
               optind = permute_from + 1;
               return EOF;
            }
            break;
         case RETURN_IN_ORDER:
            if (!is_option(argv[optind], only)) {
               optarg = argv[optind++];
               return (optopt = 1);
            }
            break;
         case REQUIRE_ORDER:
            if (!is_option(argv[optind], only))
               return EOF;
            break;
         }
      }
      /* we've got an option, so parse it */

      /* first, is it a long option? */
      if (longopts != NULL
         && (memcmp(argv[optind], "--", 2) == 0
            || (only && argv[optind][0] == '+'))
         && optwhere == 1) {
         /* handle long options */
         if (memcmp(argv[optind], "--", 2) == 0)
            optwhere = 2;
         longopt_match = -1;
         possible_arg = strchr(argv[optind] + optwhere, '=');
         if (possible_arg == NULL) {
            /* no =, so next argv might be arg */
```

```
            match_chars = strlen(argv[optind]);
            possible_arg = argv[optind] + match_chars;
            match_chars = match_chars - optwhere;
        }
        else
            match_chars = (possible_arg - argv[optind]) - optwhere;
        for (optindex = 0; longopts[optindex].name != NULL; optindex++)
{
            if (memcmp(argv[optind] + optwhere,
                    longopts[optindex].name,
                    match_chars) == 0) {
                /* do we have an exact match? */
                if (match_chars == (int)
(strlen(longopts[optindex].name))) {
                    longopt_match = optindex;
                    break;
                }
                /* do any characters match? */
                else {
                    if (longopt_match < 0)
                        longopt_match = optindex;
                    else {
                        /* we have ambiguous options */
                        if (opterr)
                            fprintf(stderr, "%s: option `%s' is
ambiguous "
                                    "(could be `--%s' or `--%s')\n",
                                    argv[0],
                                    argv[optind],
                                    longopts[longopt_match].name,
                                    longopts[optindex].name);
                        return (optopt = '?');
                    }
                }
            }
        }
        if (longopt_match >= 0)
            has_arg = longopts[longopt_match].has_arg;
    }
    /* if we didn't find a long option, is it a short option? */
    if (longopt_match < 0 && shortopts != NULL) {
        cp = strchr(shortopts, argv[optind][optwhere]);
        if (cp == NULL) {
            /* couldn't find option in shortopts */
```

```
        if (opterr)
            fprintf(stderr,
                    "%s: invalid option -- `-%c'\n",
                    argv[0],
                    argv[optind][optwhere]);
        optwhere++;
        if (argv[optind][optwhere] == '\0') {
            optind++;
            optwhere = 1;
        }
        return (optopt = '?');
    }
    has_arg = ((cp[1] == ':')
             ? ((cp[2] == ':') ? OPTIONAL_ARG : REQUIRED_ARG)
             : NO_ARG);
    possible_arg = argv[optind] + optwhere + 1;
    optopt = *cp;
}
/* get argument and reset optwhere */
arg_next = 0;
switch (has_arg) {
case OPTIONAL_ARG:
    if (*possible_arg == '=')
        possible_arg++;
    if (*possible_arg != '\0') {
        optarg = possible_arg;
        optwhere = 1;
    }
    else
        optarg = NULL;
    break;
case REQUIRED_ARG:
    if (*possible_arg == '=')
        possible_arg++;
    if (*possible_arg != '\0') {
        optarg = possible_arg;
        optwhere = 1;
    }
    else if (optind + 1 >= argc) {
        if (opterr) {
            fprintf(stderr, "%s: argument required for option `",
                    argv[0]);
            if (longopt_match >= 0)
                fprintf(stderr, "--%s'\n",
```

```
longopts[longopt_match].name);
                else
                    fprintf(stderr, "-%c'\n", *cp);
            }
            optind++;
            return (optopt = ':');
        }
        else {
            optarg = argv[optind + 1];
            arg_next = 1;
            optwhere = 1;
        }
        break;
    case NO_ARG:
        if (longopt_match < 0) {
            optwhere++;
            if (argv[optind][optwhere] == '\0')
                optwhere = 1;
        }
        else
            optwhere = 1;
        optarg = NULL;
        break;
    }

    /* do we have to permute or otherwise modify optind? */
    if (ordering == PERMUTE && optwhere == 1 && num_nonopts != 0) {
        permute(argv + permute_from, num_nonopts, 1 + arg_next);
        optind = permute_from + 1 + arg_next;
    }
    else if (optwhere == 1)
        optind = optind + 1 + arg_next;

    /* finally return */
    if (longopt_match >= 0) {
        if (longind != NULL)
            *longind = longopt_match;
        if (longopts[longopt_match].flag != NULL) {
            *(longopts[longopt_match].flag) =
longopts[longopt_match].val;
            return 0;
        }
        else
            return longopts[longopt_match].val;
```

```
    }
    else
        return optopt;
}

int getopt_long(int argc, char **argv, char *shortopts,
                GETOPT_LONG_OPTION_T * longopts, int *longind)
{
    return getopt_internal(argc, argv, shortopts, longopts, longind, 0);
}

void help(void)
{
    puts( "OPTIONS" );
    puts( "" );
    puts( "-i, --initial   When shrinking, make"
          " initial spaces/tabs on a line tabs" );
    puts( "              and expand every other"
          " tab on the line into spaces." );
    puts( "-t=tablist,     "
          "Specify list of tab stops.  "
          "Default is every 8 characters." );
    puts( "--tabs=tablist, "
          "The parameter tablist is a list"
          " of tab stops separated by" );
    puts( "-tablist       "
          "commas; if no commas are present,"
          " the program will put a" );
    puts( "              "
          "tab stop every x places, "
          "with x being the number in the" );
    puts( "              parameter." );
    puts( "" );
    puts( "--help         Print usage message"
          " and exit successfully." );
    puts( "" );
    puts( "--version      Print version "
          "information and exit successfully." );
}

void version(void)
{
    puts( "detab - expand tabs into spaces" );
    puts( "Version 1.0" );
```

```
    puts( "Written by Gregory Pietsch" );
}

/* allocate memory, die on error */
void *xmalloc(size_t n)
{
    void *p = malloc(n);

    if (p == NULL) {
        fprintf(stderr, "%s: out of memory\n", program_name);
        exit(EXIT_FAILURE);
    }
    return p;
}

/* reallocate memory, die on error */
void *xrealloc(void *p, size_t n)
{
    void *s;

    if (n == 0) {
        if (p != NULL)
            free(p);
        return NULL;
    }
    if (p == NULL)
        return xmalloc(n);
    s = realloc(p, n);
    if (s == NULL) {
        fprintf(stderr, "%s: out of memory\n", program_name);
        exit(EXIT_FAILURE);
    }
    return s;
}

/* Determine the location of the first character in the string s1
 * that is not a character in s2.  The terminating null is not
 * considered part of the string.
 */
char *xstrcpbrk(char *s1, char *s2)
{
    char *sc1;
    char *sc2;
```

```
    for (sc1 = s1; *sc1 != '\0'; sc1++)
        for (sc2 = s2;; sc2++)
            if (*sc2 == '\0')
                return sc1;
            else if (*sc1 == *sc2)
                break;
    return NULL;              /* terminating nulls match */
}

/* compare function for qsort() */
int ul_cmp(const void *a, const void *b)
{
    unsigned long *ula = (unsigned long *) a;
    unsigned long *ulb = (unsigned long *) b;

    return (*ula < *ulb) ? -1 : (*ula > *ulb);
}

/* handle a tab stop list -- assumes param isn't NULL */
void handle_tab_stops(char *s)
{
    char *p;
    unsigned long ul;
    size_t len = strlen(s);

    if (xstrcpbrk(s, "0123456789,") != NULL) {
        /* funny param */
        fprintf(stderr, "%s: invalid parameter\n", program_name);
        exit(EXIT_FAILURE);
    }
    if (strchr(s, ',') == NULL) {
        tab_every = strtoul(s, NULL, 10);
        if (tab_every == 0)
            tab_every = 8;
    }
    else {
        tab_stop_list = xrealloc(tab_stop_list,
             (num_tab_stops_allocked += len) * (sizeof(unsigned
long)));
        for (p = s; (p = strtok(p, ",")) != NULL; p = NULL) {
            ul = strtoul(p, NULL, 10);
            tab_stop_list[num_tab_stops++] = ul;
        }
        qsort(tab_stop_list, num_tab_stops, sizeof(unsigned long),
```

```
            ul_cmp);
    }
}

void parse_args(int argc, char **argv)
{
    int opt;

    do {
        switch ((opt = getopt_long(argc, argv, shortopts, longopts,
NULL))) {
        case 'i':             /* initial */
            flag_initial = 1;
            break;
        case 't':             /* tab stops */
            handle_tab_stops(optarg);
            break;
        case '?':             /* invalid option */
            fprintf(stderr,"For help, type:\n\t%s --help\n",
program_name);
            exit(EXIT_FAILURE);
        case 1:
        case 0:
            if (show_help || show_version) {
                if (show_help)
                    help();
                if (show_version)
                    version();
                exit(EXIT_SUCCESS);
            }
            break;
        default:
            break;
        }
    } while (opt != EOF);
}

/* output exactly n spaces */
void output_spaces(size_t n)
{
    int x = n;               /* assume n is small */

    printf("%*s", x, "");
}
```

```
/* get next highest tab stop */
unsigned long get_next_tab(unsigned long x)
{
    size_t i;

    if (tab_stop_list == NULL) {
        /* use tab_every */
        x += (tab_every - (x % tab_every));
        return x;
    }
    else {
        for (i = 0; i < num_tab_stops && tab_stop_list[i] <= x; i++);
        return (i >= num_tab_stops) ? 0 : tab_stop_list[i];
    }
}

/* the function that does the dirty work */
void tab(FILE * f)
{
    unsigned long linelength = 0;
    int c;
    int in_initials = 1;
    size_t num_spaces = 0;
    unsigned long next_tab;

    while ((c = getc(f)) != EOF) {
        if (c != ' ' && c != '\t' && num_spaces > 0) {
            /* output spaces and possible tabs */
            if (flag_expand
                || (flag_initial && !in_initials)
                || num_spaces == 1) {
                /* output spaces anyway */
                output_spaces(num_spaces);
                linelength += num_spaces;
                num_spaces = 0;
            }
            else
                while (num_spaces != 0) {
                    next_tab = get_next_tab(linelength);
                    if (next_tab > 0 && next_tab <= linelength +
num_spaces) {
                        /* output a tab */
                        putc('\t', stdout);
```

```
                    num_spaces -= (next_tab - linelength);
                    linelength = next_tab;
                }
                else {
                    /* output spaces */
                    output_spaces(num_spaces);
                    linelength += num_spaces;
                    num_spaces = 0;
                }
            }
        }
        switch (c) {
        case ' ':             /* space */
            num_spaces++;
            break;
        case '\b':            /* backspace */
            /* preserve backspaces in output; decrement length for
tabbing
             * purposes
             */
            putc(c, stdout);
            if (linelength > 0)
                linelength--;
            break;
        case '\n':            /* newline */
            putc(c, stdout);
            in_initials = 1;
            linelength = 0;
            break;
        case '\t':            /* tab */
            next_tab = get_next_tab(linelength + num_spaces);
            if (next_tab == 0) {
                while ((next_tab = get_next_tab(linelength)) != 0) {
                    /* output tabs */
                    putc('\t', stdout);
                    num_spaces -= (next_tab - linelength);
                    linelength = next_tab;
                }
                /* output spaces */
                output_spaces(num_spaces);
                num_spaces = 0;
                putc('\t', stdout);
                linelength += num_spaces + 1;
            }
```

```
            else
                num_spaces = next_tab - linelength;
            break;
        default:
            putc(c, stdout);
            in_initials = 0;
            linelength++;
            break;
        }
    }
}

int main(int argc, char **argv)
{
    int i;
    FILE *fp;
    char *allocked_argvs = xmalloc(argc + 1);
    char **new_argv = xmalloc((argc + 1) * sizeof(char *));
    char *p;

    program_name = argv[0];
    memset(allocked_argvs, 0, argc + 1);
    for (i = 0; i < argc; i++) {
        p = argv[i];
        if (isdigit(p[1])) {
            new_argv[i] = xmalloc(strlen(p) + 2);
            sprintf(new_argv[i], "-t%s", p + 1);
            allocked_argvs[i] = 1;
        }
        else
            new_argv[i] = p;
    }
    new_argv[argc] = NULL;
    parse_args(argc, new_argv);
    if (optind == argc)
        tab(stdin);
    else {
        for (i = optind; i < argc; i++) {
            if (strcmp(argv[i], "-") == 0)
                fp = stdin;
            else {
                fp = fopen(argv[i], "r");
                if (fp == NULL) {
                    fprintf(stderr, "%s: can't open %s\n",
```

```
                        argv[0], argv[i]);
                abort();
            }
        }
        tab(fp);
        if (fp != stdin)
            fclose(fp);
    }
}
/* free everything we can */
for (i = 0; i < argc; i++)
    if (allocked_argvs[i])
        free(new_argv[i]);
free(allocked_argvs);
if (tab_stop_list != NULL)
    free(tab_stop_list);
return EXIT_SUCCESS;
}

/* END OF FILE entab.c */
```

Answer to Exercise 5-13, page 118

Write the program `tail`, which prints the last `n` lines of its input. By default, `n` is 10, say, but it can be changed by an optional argument, so that

```
tail -n
```

prints the last `n` lines. The program should behave rationally no matter how unreasonable the input or the value of `n`. Write the program so it makes the best use of available storage; lines should be stored as in the sorting program of Section 5.6, not in a two-dimensional array of fixed size.

Gregory Pietsch's solution

```
/*************************************************************************
********

tail.c - Source code for the tail command

AUTHOR: Gregory Pietsch <gkp1@flash.net>

DESCRIPTION:

tail prints the last part of each file on the command line (10 lines by
default); it reads from standard input if no files are given or when a
```

```
filename of `-' is encountered.  If more than one file is given, it
prints a header consisting of the file's name enclosed in `==>' and `<==' before
the output for each file.

There are two option formats for tail:  the new one, in which numbers are
arguments to the option letters; and the old one, in which the number
precedes any option letters.  In this version, the old format is barely
supported.  Supporting it fully is left as an exercise to the reader ;-).

GNU's -f (or --follow) option is not supported.  With that option, the
program loops forever on the assumption that the file being tailed is
growing.  I couldn't figure out how to determine if the program is reading
from a pipe in ANSI C; this option is ignored if reading from a pipe.

*****************************************************************
*******/

/* include files */
#include <ctype.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

/* macros */

#define NO_ARG        0
#define REQUIRED_ARG   1
#define OPTIONAL_ARG   2

 /* how many characters will fill one's tail (literally) */
#define TAIL_BUFFER_SIZE 16384

 /* how much for a string buffer */
#define TAIL_STRING_BUFFER_SIZE 256

 /* need MIN */
#ifndef MIN
#define MIN(x,y) ((x)<(y)?(x):(y))
#endif

/* types */

typedef enum VERBOSITY_T {
```

```
    NEVER,
    SOMETIMES,
    ALWAYS
} VERBOSITY_T;

typedef struct LINE_QUEUE_EL_T {
    char *s;
    struct LINE_QUEUE_EL_T *next;
} LINE_QUEUE_EL_T;

typedef struct LINE_QUEUE_T {
    struct LINE_QUEUE_EL_T *first;
    struct LINE_QUEUE_EL_T *last;
    unsigned long num_elements;
} LINE_QUEUE_T;

/* GETOPT_LONG_OPTION_T: The type of long option */
typedef struct GETOPT_LONG_OPTION_T {
    char *name;               /* the name of the long option */
    int has_arg;              /* one of the above macros */
    int *flag;                /* determines if getopt_long() returns a
                               * value for a long option; if it is
                               * non-NULL, 0 is returned as a function
                               * value and the value of val is stored in
                               * the area pointed to by flag. Otherwise,
                               * val is returned. */
    int val;                  /* determines the value to return if flag is
                               * NULL. */
} GETOPT_LONG_OPTION_T;

typedef enum GETOPT_ORDERING_T {
    PERMUTE,
    RETURN_IN_ORDER,
    REQUIRE_ORDER
} GETOPT_ORDERING_T;

/* globally-defined variables */
char *optarg = NULL;
int optind = 0;
int opterr = 1;
int optopt = '?';

/* statically-defined variables */
```

```
static int show_help = 0;
static int show_version = 0;
static char *shortopts = "c:l:n:qv";
static GETOPT_LONG_OPTION_T longopts[] =
{
   {"bytes", REQUIRED_ARG, NULL, 'c'},
   {"lines", REQUIRED_ARG, NULL, 'n'},
   {"quiet", NO_ARG, NULL, 'q'},
   {"silent", NO_ARG, NULL, 'q'},
   {"verbose", NO_ARG, NULL, 'v'},

   {"help", NO_ARG, &show_help, 1},
   {"version", NO_ARG, &show_version, 1},
   {NULL, 0, 0, 0}
};
static char *program_name;
static int flag_bytes = 0;
static VERBOSITY_T flag_verbosity = SOMETIMES;
static unsigned long number = 0;
static int flag_skip = 0;

/* functions */

/* reverse_argv_elements:  reverses num elements starting at argv */
static void reverse_argv_elements(char **argv, int num)
{
   int i;
   char *tmp;

   for (i = 0; i < (num >> 1); i++) {
      tmp = argv[i];
      argv[i] = argv[num - i - 1];
      argv[num - i - 1] = tmp;
   }
}

/* permute: swap two blocks of argv-elements given their lengths */
static void permute(char **argv, int len1, int len2)
{
   reverse_argv_elements(argv, len1);
   reverse_argv_elements(argv, len1 + len2);
   reverse_argv_elements(argv, len2);
}
```

```
/* is_option: is this argv-element an option or the end of the option list?
*/
static int is_option(char *argv_element, int only)
{
    return ((argv_element == NULL)
           || (argv_element[0] == '-')
           || (only && argv_element[0] == '+'));
}

/* getopt_internal:  the function that does all the dirty work */
static int getopt_internal(int argc, char **argv, char *shortopts,
              GETOPT_LONG_OPTION_T * longopts, int *longind, int only)
{
    GETOPT_ORDERING_T ordering = PERMUTE;
    static size_t optwhere = 0;
    size_t permute_from = 0;
    int num_nonopts = 0;
    int optindex = 0;
    size_t match_chars = 0;
    char *possible_arg = NULL;
    int longopt_match = -1;
    int has_arg = -1;
    char *cp;
    int arg_next = 0;

    /* first, deal with silly parameters and easy stuff */
    if (argc == 0 || argv == NULL || (shortopts == NULL && longopts ==
NULL))
        return (optopt = '?');
    if (optind >= argc || argv[optind] == NULL)
        return EOF;
    if (strcmp(argv[optind], "--") == 0) {
        optind++;
        return EOF;
    }
    /* if this is our first time through */
    if (optind == 0)
        optind = optwhere = 1;

    /* define ordering */
    if (shortopts != NULL && (*shortopts == '-' || *shortopts == '+'))
{
        ordering = (*shortopts == '-') ? RETURN_IN_ORDER : REQUIRE_ORDER;
        shortopts++;
```

```
    }
    else
        ordering = (getenv("POSIXLY_CORRECT") != NULL) ? REQUIRE_ORDER :
            PERMUTE;

    /*
     * based on ordering, find our next option, if we're at the beginning
of
     * one
     */
    if (optwhere == 1) {
        switch (ordering) {
        case PERMUTE:
            permute_from = optind;
            num_nonopts = 0;
            while (!is_option(argv[optind], only)) {
                optind++;
                num_nonopts++;
            }
            if (argv[optind] == NULL) {
                /* no more options */
                optind = permute_from;
                return EOF;
            } else if (strcmp(argv[optind], "--") == 0) {
                /* no more options, but have to get `--' out of the way */
                permute(argv + permute_from, num_nonopts, 1);
                optind = permute_from + 1;
                return EOF;
            }
            break;
        case RETURN_IN_ORDER:
            if (!is_option(argv[optind], only)) {
                optarg = argv[optind++];
                return (optopt = 1);
            }
            break;
        case REQUIRE_ORDER:
            if (!is_option(argv[optind], only))
                return EOF;
            break;
        }
    }
    /* we've got an option, so parse it */
```

```
    /* first, is it a long option? */
    if (longopts != NULL
        && (memcmp(argv[optind], "--", 2) == 0
            || (only && argv[optind][0] == '+'))
        && optwhere == 1) {
        /* handle long options */
        if (memcmp(argv[optind], "--", 2) == 0)
            optwhere = 2;
        longopt_match = -1;
        possible_arg = strchr(argv[optind] + optwhere, '=');
        if (possible_arg == NULL) {
            /* no =, so next argv might be arg */
            match_chars = strlen(argv[optind]);
            possible_arg = argv[optind] + match_chars;
            match_chars = match_chars - optwhere;
        }
        else
            match_chars = (possible_arg - argv[optind]) - optwhere;
        for (optindex = 0; longopts[optindex].name != NULL; optindex++)
{
            if (memcmp(argv[optind] + optwhere,
                       longopts[optindex].name,
                       match_chars) == 0) {
                /* do we have an exact match? */
                if (match_chars == (int)(strlen(longopts[optindex].name)))
{
                    longopt_match = optindex;
                    break;
                }
                /* do any characters match? */
                else {
                    if (longopt_match < 0)
                        longopt_match = optindex;
                    else {
                        /* we have ambiguous options */
                        if (opterr)
                            fprintf(stderr, "%s: option `%s' is ambiguous "
                                    "(could be `--%s' or `--%s')\n",
                                    argv[0],
                                    argv[optind],
                                    longopts[longopt_match].name,
                                    longopts[optindex].name);
                        return (optopt = '?');
                    }
```

```
            }
        }
    }
    if (longopt_match >= 0)
        has_arg = longopts[longopt_match].has_arg;
}
/* if we didn't find a long option, is it a short option? */
if (longopt_match < 0 && shortopts != NULL) {
    cp = strchr(shortopts, argv[optind][optwhere]);
    if (cp == NULL) {
        /* couldn't find option in shortopts */
        if (opterr)
            fprintf(stderr,
                    "%s: invalid option -- `-%c'\n",
                    argv[0],
                    argv[optind][optwhere]);
        optwhere++;
        if (argv[optind][optwhere] == '\0') {
            optind++;
            optwhere = 1;
        }
        return (optopt = '?');
    }
    has_arg = ((cp[1] == ':')
             ? ((cp[2] == ':') ? OPTIONAL_ARG : REQUIRED_ARG)
             : NO_ARG);
    possible_arg = argv[optind] + optwhere + 1;
    optopt = *cp;
}
/* get argument and reset optwhere */
arg_next = 0;
switch (has_arg) {
case OPTIONAL_ARG:
    if (*possible_arg == '=')
        possible_arg++;
    if (*possible_arg != '\0') {
        optarg = possible_arg;
        optwhere = 1;
    }
    else
        optarg = NULL;
    break;
case REQUIRED_ARG:
    if (*possible_arg == '=')
```

```
            possible_arg++;
        if (*possible_arg != '\0') {
            optarg = possible_arg;
            optwhere = 1;
        }
        else if (optind + 1 >= argc) {
            if (opterr) {
                fprintf(stderr, "%s: argument required for option `",
                        argv[0]);
                if (longopt_match >= 0)
                    fprintf(stderr, "--%s'\n",
longopts[longopt_match].name);
                else
                    fprintf(stderr, "-%c'\n", *cp);
            }
            optind++;
            return (optopt = ':');
        }
        else {
            optarg = argv[optind + 1];
            arg_next = 1;
            optwhere = 1;
        }
        break;
    case NO_ARG:
        if (longopt_match < 0) {
            optwhere++;
            if (argv[optind][optwhere] == '\0')
                optwhere = 1;
        }
        else
            optwhere = 1;
        optarg = NULL;
        break;
    }

    /* do we have to permute or otherwise modify optind? */
    if (ordering == PERMUTE && optwhere == 1 && num_nonopts != 0) {
        permute(argv + permute_from, num_nonopts, 1 + arg_next);
        optind = permute_from + 1 + arg_next;
    }
    else if (optwhere == 1)
        optind = optind + 1 + arg_next;
```

```
   /* finally return */
   if (longopt_match >= 0) {
      if (longind != NULL)
         *longind = longopt_match;
      if (longopts[longopt_match].flag != NULL) {
         *(longopts[longopt_match].flag) =
longopts[longopt_match].val;
         return 0;
      }
      else
         return longopts[longopt_match].val;
   }
   else
      return optopt;
}

int getopt_long(int argc, char **argv, char *shortopts,
              GETOPT_LONG_OPTION_T * longopts, int *longind)
{
   return getopt_internal(argc, argv, shortopts, longopts, longind, 0);
}

void help(void)
{
   puts( "OPTIONS" );
   puts( "" );
   puts( "-c N, --bytes N        Print last N bytes.  "
                           "N is a nonzero integer," );
   puts( "                     optionally followed by one of "
                          "the following" );
   puts( "                     characters:" );
   puts( "" );
   puts( "                     b      512-byte blocks." );
   puts( "                     k      1-kilobyte blocks." );
   puts( "                     m      1-megabyte blocks." );
   puts( "" );
   puts( "-N, -l N, -n N,        Print last N lines." );
   puts( "--lines N" );
   puts( "" );
   puts( "-q, --quiet,           Never print filename headers.  "
                           "Normally, filename" );
   puts( "--silent               headers are printed if and only"
                          " if more than one file" );
   puts( "                     is given on the command line." );
```

```
    puts( "" );
    puts( "-v, --verbose          Always print filename headers." );
    puts( "" );
    puts( "--help               Print usage message and exit
successfully.");
    puts( "" );
    puts( "--version             Print version"
                            " information and exit successfully." );
}

void version(void)
{
    puts( "tail - output the last part of files" );
    puts( "Version 1.0" );
    puts( "Written by Gregory Pietsch" );
}

/* allocate memory, die on error */
void *xmalloc(size_t n)
{
    void *p = malloc(n);

    if (p == NULL) {
        fprintf(stderr, "%s: out of memory\n", program_name);
        exit(EXIT_FAILURE);
    }
    return p;
}

/* reallocate memory, die on error */
void *xrealloc(void *p, size_t n)
{
    void *s;

    if (n == 0) {
        if (p != NULL)
            free(p);
        return NULL;
    }
    if (p == NULL)
        return xmalloc(n);
    s = realloc(p, n);
    if (s == NULL) {
        fprintf(stderr, "%s: out of memory\n", program_name);
```

```
        exit(EXIT_FAILURE);
    }
    return s;
}

/* get string duplicate */
char *xstrdup(char *s)
{
    char *p = xmalloc(strlen(s) + 1);

    strcpy(p, s);
    return p;
}

/* queue stuff - get fresh queue */
LINE_QUEUE_T *lq_create(void)
{
    LINE_QUEUE_T *lq = xmalloc(sizeof LINE_QUEUE_T);

    lq->first = NULL;
    lq->last = NULL;
    lq->num_elements = 0;
    return lq;
}

/* put an item onto the queue */
void lq_enq(LINE_QUEUE_T * lq, char *s)
{
    LINE_QUEUE_EL_T *lq_el = xmalloc(sizeof LINE_QUEUE_EL_T);

    lq_el->s = xstrdup(s);
    lq_el->next = NULL;
    if (lq->first == NULL && lq->last == NULL) {
        /* first element */
        lq->first = lq->last = lq_el;
        lq->num_elements = 1;
    }
    else {
        /* tack onto end */
        lq->last->next = lq_el;
        lq->last = lq_el;
        lq->num_elements++;
    }
}
```

```
/* take an item off the queue */
char *lq_deq(LINE_QUEUE_T * lq)
{
    char *s;
    LINE_QUEUE_EL_T *lq_el;

    if (lq->first == NULL)
        return NULL;
    lq_el = lq->first;
    s = lq_el->s;
    if (lq->first == lq->last)
        lq->first = lq->last = NULL;
    else
        lq->first = lq->first->next;
    free(lq_el);
    lq->num_elements--;
    return s;
}

/* output number lines -- this function is tough because I can only
 * use fseek() to rewind a text stream (See ISO C 7.9.9.2 if you don't
 * believe me).
 */
void tail_lines(FILE * f)
{
    char buffer[TAIL_BUFFER_SIZE];
    size_t num_read;
    int last_is_nl = 0;
    unsigned long num_skipped = 0;
    int c;
    LINE_QUEUE_T *lq = NULL;
    char *s;
    size_t s_size = 0;
    size_t s_allocked = 0;
    char *p;

    if (flag_skip) {
        /* skip a bunch of lines, output everything else */
        while ((c = getc(f)) != EOF && num_skipped < number) {
            if (c == '\n')
                num_skipped++;
        }
        while ((num_read = fread(buffer, 1, TAIL_BUFFER_SIZE, f)) != 0)
```

```
{
          fwrite(buffer, 1, num_read, stdout);
          last_is_nl = (buffer[num_read - 1] == '\n');
       }
       if (!last_is_nl)
          fputc('\n', stdout);
   }
   else {
       lq = lq_create();
       s = xmalloc(TAIL_STRING_BUFFER_SIZE);
       s_allocked = TAIL_STRING_BUFFER_SIZE;
       while ((c = getc(f)) != EOF) {
          /* add to s, if not at eof or end of line */
          if (c != '\n') {
             if (s_size == s_allocked - 1) {
                s_allocked += TAIL_STRING_BUFFER_SIZE;
                s = xrealloc(s, s_allocked);
             }
             s[s_size++] = c;
          }
          else {
             /* enqueue s, possibly dequeueing if we don't need a
line */
             s[s_size] = '\0';
             lq_enq(lq, s);
             if (lq->num_elements > number)
                free(lq_deq(lq));
             s_size = 0;
          }
       }
       while (lq->num_elements != 0) {
          /* print out strings */
          p = lq_deq(lq);
          puts(p);
          free(p);
       }
       free(s);
       free(lq);
   }
}

/* output number characters, or skip over number characters */
void tail_chars(FILE * f)
{
```

```
    char buffer[TAIL_BUFFER_SIZE];
    size_t num_read;
    int last_is_nl = 0;
    long lnum = number;

    if (flag_skip)
        fseek(f, lnum, SEEK_SET);
    else
        fseek(f, -lnum, SEEK_END);
    while ((num_read = fread(buffer, 1, TAIL_BUFFER_SIZE, f)) != 0) {
        fwrite(buffer, 1, num_read, stdout);
        last_is_nl = (buffer[num_read - 1] == '\n');
    }
    if (!last_is_nl)
        fputc('\n', stdout);
}

void parse_args(int argc, char **argv)
{
    int opt;
    char *p;
    int flag_found_number = 0;
    int verbosity_changed = 0;

    do {
        switch ((opt = getopt_long(argc, argv, shortopts, longopts, NULL)))
{
        case 'c':             /* print bytes */
            if (flag_found_number) {
                fprintf(stderr, "%s: invalid arguments\s", program_name);
                abort();
            }
            flag_bytes = 1;
            p = optarg;
            if (*p == '+') {
                flag_skip = 1;
                p++;
            }
            for (number = 0;
                 isdigit(*p);
                 number = number * 10 + (*p++ - '0'));
            switch (*p) {
            case 'b':         /* 512-byte blocks */
                number *= 512;
```

```
            break;
        case 'k':           /* kilobyte blocks */
            number *= 1024;
            break;
        case 'm':           /* megabyte blocks */
            number *= 1048576;
            break;
        default:
            break;
        }
        flag_found_number = 1;
        break;
    case 'l':
    case 'n':               /* lines */
        if (flag_found_number) {
            fprintf(stderr, "%s: invalid arguments\s", program_name);
            abort();
        }
        flag_bytes = 0;
        p = optarg;
        if (*p == '+') {
            flag_skip = 1;
            p++;
        }
        number = strtoul(p, NULL, 10);
        flag_found_number = 1;
        break;
    case 'q':               /* quiet */
        if (verbosity_changed) {
            fprintf(stderr, "%s: invalid arguments\s", program_name);
            abort();
        }
        verbosity_changed = 1;
        flag_verbosity = NEVER;
        break;
    case 'v':               /* verbose */
        if (verbosity_changed) {
            fprintf(stderr, "%s: invalid arguments\s", program_name);
            abort();
        }
        verbosity_changed = 1;
        flag_verbosity = ALWAYS;
        break;
    case '?':               /* invalid option */
```

```
            fprintf(stderr, "For help, type:\n\t%s --help\n",
program_name);
            exit(EXIT_FAILURE);
        case 1:
        case 0:
            if (show_help || show_version) {
                if (show_help)
                    help();
                if (show_version)
                    version();
                exit(EXIT_SUCCESS);
            }
            break;
        default:
            break;
        }
    } while (opt != EOF);
    if (flag_found_number == 0 || number == 0) {
        /* didn't find anything, so set default */
        flag_bytes = 0;
        number = 10;
    }
}

int main(int argc, char **argv)
{
    int i;
    int j;
    unsigned long ul;
    char **new_argv = xmalloc((argc + 1) * (sizeof(char *)));
    char *allocked_argvs = xmalloc(argc + 1);
    char *p;
    char *s;
    char *t;
    FILE *f;
    int flag_plus = 0;

    memset(allocked_argvs, 0, argc + 1);
    new_argv[0] = program_name = argv[0];
    /* deal with silly old-format arguments */
    for (i = 1, j = 1; i < argc; i++) {
        p = argv[i];
        flag_plus = 0;
        /* handle options first */
```

```
if (*p == '-' || *p == '+') {
   if (isdigit(p[1]) || p[1] == '+' || *p == '+') {
      /* rearrange p */
      s = xmalloc(strlen(p) + 3);
      t = s;
      *t++ = '-';
      if (*p == '-')
         p++;
      ul = 0;
      if (*p == '+') {
         flag_plus = 1;
         p++;
      }
      while (isdigit(*p)) {
         ul = ul * 10 + (*p - '0');
         p++;
      }
      if (strchr(p, 'q') != NULL)
         *t++ = 'q';
      if (strchr(p, 'v') != NULL)
         *t++ = 'v';
      if (strpbrk(p, "cbkm") != NULL)
         *t++ = 'c';
      if (strchr(p, 'l') != NULL)
         *t++ = 'l';
      if (strchr(p, 'n') != NULL || t[-1] == '-')
         *t++ = 'n';
      if (flag_plus)
         *t++ = '+';
      sprintf(t, "%lu", ul);
      t += strlen(t);
      if (strchr(p, 'b') != NULL)
         *t++ = 'b';
      if (strchr(p, 'k') != NULL)
         *t++ = 'k';
      if (strchr(p, 'm') != NULL)
         *t++ = 'm';
      *t = '\0';
      new_argv[j] = s;
      allocked_argvs[j++] = 1;
   }
   else
      new_argv[j++] = argv[i];
}
```

```
}
for (i = 1; i < argc; i++) {
    /* handle file names */
    p = argv[i];
    if (*p != '-')
        new_argv[j++] = p;
}
new_argv[argc] = NULL;
parse_args(argc, new_argv);
if (optind == argc
    || (optind == argc - 1 && strcmp(argv[optind], "-") == 0)) {
    /* no more argv-elements, tail stdin */
    if (flag_verbosity == ALWAYS)
        puts("==> standard input <==");
    flag_bytes ? tail_chars(stdin) : tail_lines(stdin);
}
else if (optind == argc - 1) {
    /* one file */
    f = fopen(new_argv[optind], flag_bytes ? "rb" : "r");
    if (f == NULL) {
        fprintf(stderr, "%s: Can't open file %s\n",
                program_name, new_argv[optind]);
        abort();
    }
    if (flag_verbosity == ALWAYS)
        printf("==> %s <==\n", new_argv[optind]);
    flag_bytes ? tail_chars(f) : tail_lines(f);
    fclose(f);
}
else {
    /* multiple files */
    for (i = optind; i < argc; i++) {
        if (strcmp(new_argv[i], "-") == 0) {
            f = stdin;
            if (flag_verbosity != NEVER)
                puts("==> standard input <==");
        }
        else {
            f = fopen(new_argv[i], flag_bytes ? "rb" : "r");
            if (f == NULL) {
                fprintf(stderr, "%s: can't open %s\n",
                        argv[0], argv[i]);
                abort();
            }
```

```
            if (flag_verbosity != NEVER)
                printf("==> %s <==\n", new_argv[i]);
        }
        flag_bytes ? tail_chars(f) : tail_lines(f);
        if (f != stdin)
            fclose(f);
      }
   }
   /* free all we can */
   for (i = 1; i <= argc; i++)
      if (allocked_argvs[i])
         free(new_argv[i]);
   free(allocked_argvs);
   return EXIT_SUCCESS;
}

/* END OF FILE tail.c */
```

Steven Huang's solution

```
/* K&R Exercise 5-13 */
/* Steven Huang */

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

#define DEFAULT_NUM_LINES     10
#define MAX_LINE_LEN         1000

/*
   Points of interest for a novice:

   1.  atoi() has a normally annoying property of not being able to
       tell the caller conclusively whether the input was bad ("abc")
       or it was really zero ("0"), because it returns 0 for both
       cases.  Here, we exploit that property, because we only want
       to accept options in the form of "-n".

   2.  Try to understand how this program deals with input that
       doesn't even have as many lines as the line_ptrs[] array.
       That is, how does this program degenerate into just displaying
       everything it read?  (Hint:  what does it mean when line_ptrs[x]
```

```
      is NULL?)

   3. Using modulo arithmetic on an index to a circular array is
      a common and useful technique.  Try to understand the range
      of values that current_line (and j, later) will take.  In
      particular, why shouldn't we just do this:

      for (i = 0; i < num_lines; i++)
        if (line_ptrs[i])
          printf("%s", line_ptrs[i]);

   4. Why do we still use a "%s" to display what's inside line_ptrs,
      rather than just:

      printf(line_ptrs[i]);

   5. There is a bug in this program, where you see:

      numlines = -numlines;

      When will this break?
*/

/* K&R2 p29 */
int getline(char s[], int lim)
{
  int c, i;

  for (i = 0; i < lim - 1 && (c = getchar()) != EOF && c != '\n'; i++)
    s[i] = c;
  if (c == '\n')
    s[i++] = c;
  s[i] = '\0';
  return i;
}

/* duplicates a string */
char *dupstr(const char *s)
{
  char *p = malloc(strlen(s) + 1);

  if (p)
    strcpy(p, s);
  return p;
```

```
}

int main(int argc, char *argv[])
{
  int num_lines = DEFAULT_NUM_LINES;
  char **line_ptrs;
  char buffer[MAX_LINE_LEN];
  int i;
  unsigned j, current_line;

  if (argc > 1) {
    /*
       We use a little trick here.  The command line parameter should be
       in the form of "-n", where n is the number of lines.  We don't
       check for the "-", but just pass it to atoi() anyway, and then
       check if atoi() returned us a negative number.
    */
    num_lines = atoi(argv[1]);
    if (num_lines >= 0) {
      fprintf(stderr, "Expected -n, where n is the number of lines\n");
      return EXIT_FAILURE;
    }
    /* Now make num_lines the positive number it's supposed to be. */
    num_lines = -num_lines;
  }

   /* First, let's get enough storage for a list of n pointers... */
  line_ptrs = malloc(sizeof *line_ptrs * num_lines);
  if (!line_ptrs) {
    fprintf(stderr, "Out of memory.  Sorry.\n");
    return EXIT_FAILURE;
  }
  /* and make them all point to NULL */
  for (i = 0; i < num_lines; i++)
    line_ptrs[i] = NULL;

  /* Now start reading */
  current_line = 0;
  do {
    getline(buffer, sizeof buffer);
    if (!feof(stdin)) {
      if (line_ptrs[current_line]) {
        /* there's already something here */
        free(line_ptrs[current_line]);
```

```
      }
      line_ptrs[current_line] = dupstr(buffer);
      if (!line_ptrs[current_line]) {
        fprintf(stderr, "Out of memory.  Sorry.\n");
        return EXIT_FAILURE;
      }
      current_line = (current_line + 1) % num_lines;
    }
  } while (!feof(stdin));

  /* Finished reading the file, so we are ready to print the lines */
  for (i = 0; i < num_lines; i++) {
    j = (current_line + i) % num_lines;
    if (line_ptrs[j]) {
      printf("%s", line_ptrs[j]);
      free(line_ptrs[j]);
    }
  }

  return EXIT_SUCCESS;
}
```

Answer to Exercise 5-14, page 121

Modify the sort program to handle a `-r` flag, which indicates sorting in reverse (decreasing) order. Be sure that `-r` works with `-n`.

```
/* K&R Exercise 5-14 */
/* Steven Huang */

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

#define TRUE 1
#define FALSE 0

#define MAXLINES 5000      /* maximum number of lines */
char *lineptr[MAXLINES];

#define MAXLEN 1000        /* maximum length of a line */

int reverse = FALSE;
```

```c
/* K&R2 p29 */
int getline(char s[], int lim)
{
  int c, i;

  for (i = 0; i < lim - 1 && (c = getchar()) != EOF && c != '\n'; i++)
    s[i] = c;
  if (c == '\n') {
    s[i++] = c;
  }
  s[i] = '\0';
  return i;
}

/* K&R2 p109 */
int readlines(char *lineptr[], int maxlines)
{
  int len, nlines;
  char *p, line[MAXLEN];

  nlines = 0;
  while ((len = getline(line, MAXLEN)) > 0)
    if (nlines >= maxlines || (p = malloc(len)) == NULL)
      return -1;
    else {
      line[len - 1] = '\0';  /* delete the newline */
      strcpy(p, line);
      lineptr[nlines++] = p;
    }
  return nlines;
}

/* K&R2 p109 */
void writelines(char *lineptr[], int nlines)
{
  int i;

  for (i = 0; i < nlines; i++)
    printf("%s\n", lineptr[i]);
}

int pstrcmp(const void *p1, const void *p2)
{
  char * const *s1 = reverse ? p2 : p1;
```

```
  char * const *s2 = reverse ? p1 : p2;

  return strcmp(*s1, *s2);
}

int numcmp(const void *p1, const void *p2)
{
  char * const *s1 = reverse ? p2 : p1;
  char * const *s2 = reverse ? p1 : p2;
  double v1, v2;

  v1 = atof(*s1);
  v2 = atof(*s2);
  if (v1 < v2)
    return -1;
  else if (v1 > v2)
    return 1;
  else
    return 0;
}

int main(int argc, char *argv[])
{
  int nlines;
  int numeric = FALSE;
  int i;

  for (i = 1; i < argc; i++) {
    if (*argv[i] == '-') {
      switch (*(argv[i] + 1)) {
        case 'n':  numeric = TRUE;  break;
        case 'r':  reverse = TRUE;  break;
        default:
          fprintf(stderr, "invalid switch '%s'\n", argv[i]);
          return EXIT_FAILURE;
      }
    }
  }

  if ((nlines = readlines(lineptr, MAXLINES)) >= 0) {
    qsort(lineptr, nlines, sizeof(*lineptr), numeric ? numcmp : pstrcmp);
    writelines(lineptr, nlines);
    return EXIT_SUCCESS;
  } else {
```

```
    fputs("input too big to sort\n", stderr);
    return EXIT_FAILURE;
  }
}
```

Answer to Exercise 6-1, page 136

Our version of `getword` does not properly handle underscores, string constants, comments, or preprocessor control lines. Write a better version.

```
/* K&R 6-1: "Our version of getword() does not properly handle
   underscores, string constants, or preprocessor control lines.
   Write a better version."

   This is intended to be a solution to K&R 6-1 in "category 0" as
   defined by the official rules given on Richard Heathfield's "The C
   Programming Language Answers To Exercises" page, found at
   http://users.powernet.co.uk/eton/kandr2/index.html.

   For more information on the language for which this is a lexical
   analyzer, please see the comment preceding getword() below.

   Note that there is a small modification to ungetch() as defined by
   K&R.  Hopefully this lies within the rules. */

/* knr61.c - answer to K&R2 exercise 6-1.
   Copyright (C) 2000 Ben Pfaff <blp@gnu.org>.

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   modify it under the terms of the GNU General Public License as
   published by the Free Software Foundation; either version 2 of the
   License, or (at your option) any later version.

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   You should have received a copy of the GNU General Public License
   along with this program; if not, write to the Free Software
   Foundation, Inc., 59 Temple Place - Suite 330, Boston, MA
   02111-1307, USA. */
#include <ctype.h>
#include <limits.h>
```

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

/* Tokens.  Other non-whitespace characters self-represent themselves
   as tokens. */
enum token
  {
    TOK_ID = UCHAR_MAX + 1,     /* Identifier. */
    TOK_STRING,                 /* String constant. */
    TOK_CHAR,                   /* Character constant. */
    TOK_EOF                     /* End of file. */
  };

enum token getword (char *word, int lim);

static int skipws (void);
static int getstelem (char **, int *, int);

static int getch (void);
static void ungetch (int);
static void putch (char **, int *, int);

/* Main program for testing. */
int
main (void)
{
  ungetch ('\n');

  for (;;)
    {
      char word[64];
      enum token token;

      /* Get token. */
      token = getword (word, sizeof word);

      /* Print token type. */
      switch (token)
        {
        case TOK_ID:
          printf ("id");
          break;
```

```
        case TOK_STRING:
          printf ("string");
          break;

        case TOK_CHAR:
          printf ("char");
          break;

        case TOK_EOF:
          printf ("eof\n");
          return 0;

        default:
          printf ("other");
          word[0] = token;
          word[1] = '\0';
          break;
        }

      /* Print token value more or less unambiguously. */
      {
        const char *s;

        printf ("\t'");
        for (s = word; *s != '\0'; s++)
          if (isprint (*s) && *s != '\'')
            putchar (*s);
          else if (*s == '\'')
            printf ("\\'");
          else
            /* Potentially wrong. */
            printf ("\\x%02x", *s);
        printf ("'\n");
      }
    }
}

/* Parses C-like tokens from stdin:

       - Parses C identifiers and string and character constants.

       - Other characters, such as operators, punctuation, and digits
         not part of identifiers are considered as tokens in
         themselves.
```

```
      - Skip comments and preprocessor control lines.

   Does not handle trigraphs, line continuation with \, or numerous
   other special C features.

   Returns a token type.  This is either one of TOK_* above, or a single
   character in the range 0...UCHAR_MAX.

   If TOK_ID, TOK_STRING, or TOK_CHAR is returned, WORD[] is filled
   with the identifier or string value, truncated at LIM - 1
   characters and terminated with '\0'.

   For other returned token types, WORD[] is indeterminate. */
enum token
getword (char *word, int lim)
{
  int beg_line, c;

  for (;;)
    {
      beg_line = skipws ();
      c = getch ();

      if (!beg_line || c != '#')
        break;

      /* Skip preprocessor directive. */
      do
        {
          c = getch ();
          if (c == EOF)
            return TOK_EOF;
        }
      while (c != '\n');
      ungetch ('\n');
    }

  if (c == EOF)
    return TOK_EOF;
  else if (c == '_' || isalpha ((unsigned char) c))
    {
      do
        {
```

```
        putch (&word, &lim, c);
        c = getch ();
      }
    while (isalnum ((unsigned char) c) || c == '_');

    ungetch (c);
    return TOK_ID;
  }
 else if (c == '\'' || c == '"')
  {
    int quote = c;
    word[0] = '\0';
    while (getstelem (&word, &lim, quote))
      ;
    return quote == '\'' ? TOK_CHAR : TOK_STRING;
  }
 else
   return (unsigned char) c;
}

/* Skips whitespace and comments read from stdin.
   Returns nonzero if a newline was encountered, indicating that we're
   at the beginning of a line. */
static int
skipws (void)
{
  /* Classification of an input character. */
  enum class
    {
      CLS_WS = 0,             /* Whitespace. */
      CLS_BEG_CMT,            /* Slash-star beginning a comment. */
      CLS_END_CMT,            /* Star-slash ending a comment. */
      CLS_OTHER,              /* None of the above. */

      CLS_IN_CMT = 4          /* Combined with one of the above,
                                 indicates we're inside a comment. */
    };

  /* Either 0, if we're not inside a comment,
     or CLS_IN_CMT, if we are inside a comment. */
  enum class in_comment = 0;

  /* Have we encountered a newline outside a comment? */
  int beg_line = 0;
```

```
for (;;)
  {
    int c;                /* Input character. */
    enum class class;       /* Classification of `c'. */

    /* Get an input character and determine its classification. */
    c = getch ();
    switch (c)
      {
      case '\n':
        if (!in_comment)
          beg_line = 1;
        /* Fall through. */

      case ' ': case '\f': case '\r': case '\t': case '\v':
        class = CLS_WS;
        break;

      case '/':
        /* Outside a comment, slash-star begins a comment. */
        if (!in_comment)
          {
            c = getch ();
            if (c == '*')
              class = CLS_BEG_CMT;
            else
              {
                ungetch (c);
                c = '/';
                class = CLS_OTHER;
              }
          }
        else
          class = CLS_OTHER;
        break;

      case '*':
        /* Inside a comment, star-slash ends the comment. */
        if (in_comment)
          {
            c = getch ();
            if (c == '/')
              class = CLS_END_CMT;
```

```
        else
          {
            ungetch (c);
            class = CLS_OTHER;
          }
      }
    else
      class = CLS_OTHER;
    break;

  default:
    /* Other characters. */
    if (c == EOF)
      return 0;
    class = CLS_OTHER;
  }

/* Handle character `c' according to its classification
   and whether we're inside a comment. */
switch (class | in_comment)
  {
  case CLS_WS:
  case CLS_WS | CLS_IN_CMT:
  case CLS_OTHER | CLS_IN_CMT:
    break;

  case CLS_BEG_CMT:
    in_comment = CLS_IN_CMT;
    break;

  case CLS_OTHER:
    ungetch (c);
    return beg_line;

  case CLS_END_CMT | CLS_IN_CMT:
    in_comment = 0;
    break;

  case CLS_BEG_CMT | CLS_IN_CMT:
  case CLS_END_CMT:
  default:
    printf ("can't happen\n");
    break;
  }
```

```
    }
}

/* Get a character inside a quoted string or character constant.
   QUOTE is ' for a character constant or " for a quoted string.
   *WORDP points to a string being constructed that has *LIMP bytes
   available. */
static int
getstelem (char **wordp, int *limp, int quote)
{
  int c;

  /* Handle end-of-quote and EOF. */
  c = getch ();
  if (c == quote || c == EOF)
    return 0;

  /* Handle ordinary string characters. */
  if (c != '\\')
    {
      putch (wordp, limp, c);
      return 1;
    }

  /* We're in a \ escape sequence.
     Get the second character. */
  c = getch ();
  if (c == EOF)
    return 0;

  /* Handle simple single-character escapes. */
  {
    static const char escapes[] = {"''??\"\"\\\\a\ab\bf\fn\nr\rt\tv\v"};
    const char *cp = strchr (escapes, c);
    if (cp != NULL)
      {
        putch (wordp, limp, cp[1]);
        return 1;
      }
  }

  /* Handle hexadecimal and octal escapes.
     This also handles invalid escapes by default,
     doing nothing useful with them.
```

```
     That's okay because invalid escapes generate undefined behavior. */
  {
    unsigned char v = 0;

    if (c == 'x' || c == 'X')
      for (;;)
        {
          static const char hexits[] = "0123456789abcdef";
          const char *p;

          c = getch ();
          p = strchr (hexits, tolower ((unsigned char) c));
          if (p == NULL)
            break;
          v = v * 16 + (p - hexits);
        }
    else
      {
        int i;

        for (i = 0; i < 3; i++)
          {
            v = v * 8 + (c - '0');
            c = getch ();
            if (c < '0' || c > '7')
              break;
          }
      }

    putch (wordp, limp, v);
    ungetch (c);
  }

  return 1;
}

/* Capacity of putback buffer. */
#define BUFSIZE 100

/* Putback buffer. */
char buf[BUFSIZE];

/* Number of characters in putback buffer. */
int bufp = 0;
```

```c
/* Retrieves and returns a character from stdin or from the putback
   buffer.
   Returns EOF if end of file is encountered. */
int
getch (void)
{
  return bufp > 0 ? buf[--bufp] : getchar ();
}

/* Stuffs character C into the putback buffer.
   From the caller's perspective, fails silently if the putback buffer
   is full. */
void
ungetch (int c)
{
  if (c == EOF)
    return;

  if (bufp >= BUFSIZE)
    printf ("ungetch: too many characters\n");
  else
    buf[bufp++] = c;
}

/* Stuffs character C into buffer *WORDP, which has *LIMP bytes
   available.
   Advances *WORDP and reduces *LIMP as appropriate.
   Drops the character on the floor if it would overflow the buffer.
   Ensures that *WORDP is null terminated if possible. */
static void
putch (char **wordp, int *limp, int c)
{
  if (*limp > 1)
    {
      *(*wordp)++ = c;
      (*limp)--;
    }
  if (*limp > 0)
    **wordp = '\0';
}

/*
   Local variables:
```

```
   compile-command: "checkergcc -W -Wall -ansi -pedantic knr61.c -o knr61"
   End:
*/
```

Answer to Exercise 6-3, page 143

Bug (noticed by John W Krahn) fixed 11 June 2002. The noise word list was broken because it contained out-of-order data. I fixed this, and made the program more generally useful, by performing all string comparisons without regard to case.

Write a cross-referencer that prints a list of all words in a document, and, for each word, a list of the line numbers on which it occurs. Remove noise words like "the", "and," and so on.

```
/* Write a cross-referencer program that prints a list of all words in
a
 * document, and, for each word, a list of the line numbers on which it
 * occurs. Remove noise words like "the", "and," and so on.
 */


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

/* no such thing as strdup, so let's write one
 *
 * supplementary question: why did I call this function dupstr,
 * rather than strdup?
 *
 */

char *dupstr(char *s)
{
  char *p = NULL;

  if(s != NULL)
  {
    p = malloc(strlen(s) + 1);
    if(p)
    {
```

```
      strcpy(p, s);
    }
  }

  return p;
}

/* case-insensitive string comparison */
int i_strcmp(const char *s, const char *t)
{
  int diff = 0;
  char cs = 0;
  char ct = 0;

  while(diff == 0 && *s != '\0' && *t != '\0')
  {
    cs = tolower((unsigned char)*s);
    ct = tolower((unsigned char)*t);
    if(cs < ct)
    {
      diff = -1;
    }
    else if(cs > ct)
    {
      diff = 1;
    }
    ++s;
    ++t;
  }

  if(diff == 0 && *s != *t)
  {
    /* the shorter string comes lexicographically sooner */
    if(*s == '\0')
    {
      diff = -1;
    }
    else
    {
      diff = 1;
    }
  }

  return diff;
```

```
}


struct linelist
{
  struct linelist *next;
  int line;
};

struct wordtree
{
  char *word;
  struct linelist *firstline;
  struct wordtree *left;
  struct wordtree *right;
};

void printlist(struct linelist *list)
{
  if(list != NULL)
  {
    printlist(list->next);
    printf("%6d ", list->line);
  }
}

void printtree(struct wordtree *node)
{
  if(node != NULL)
  {
    printtree(node->left);
    printf("%18s  ", node->word);
    printlist(node->firstline);
    printf("\n");
    printtree(node->right);
  }
}

struct linelist *addlink(int line)
{
  struct linelist *new = malloc(sizeof *new);
  if(new != NULL)
  {
    new->line = line;
```

```
    new->next = NULL;
  }

  return new;
}

void deletelist(struct linelist *listnode)
{
  if(listnode != NULL)
  {
    deletelist(listnode->next);
    free(listnode);
  }
}

void deleteword(struct wordtree **node)
{
  struct wordtree *temp = NULL;
  if(node != NULL)
  {
    if(*node != '\0')
    {
      if((*node)->right != NULL)
      {
        temp = *node;
        deleteword(&temp->right);
      }
      if((*node)->left != NULL)
      {
        temp = *node;
        deleteword(&temp->left);
      }
      if((*node)->word != NULL)
      {
        free((*node)->word);
      }
      if((*node)->firstline != NULL)
      {
        deletelist((*node)->firstline);
      }
      free(*node);
      *node = NULL;
    }
  }
```

```
}

struct wordtree *addword(struct wordtree **node, char *word, int line)
{
  struct wordtree *wordloc = NULL;
  struct linelist *newline = NULL;
  struct wordtree *temp = NULL;
  int diff = 0;

  if(node != NULL && word != NULL)
  {
    if(NULL == *node)
    {
      *node = malloc(sizeof **node);
      if(NULL != *node)
      {
        (*node)->left = NULL;
        (*node)->right = NULL;
        (*node)->word = dupstr(word);
        if((*node)->word != NULL)
        {
          (*node)->firstline = addlink(line);
          if((*node)->firstline != NULL)
          {
            wordloc = *node;
          }
        }
      }
    }
    else
    {
      diff = i_strcmp((*node)->word, word);
      if(0 == diff)
      {
        /* we have seen this word before! add this line number to
         * the front of the line number list. Adding to the end
         * would keep them in the right order, but would take
         * longer. By continually adding them to the front, we
         * take less time, but we pay for it at the end by having
         * to go to the end of the list and working backwards.
         * Recursion makes this less painful than it might have been.
         */
        newline = addlink(line);
        if(newline != NULL)
```

```
      {
        wordloc = *node;
        newline->next = (*node)->firstline;
        (*node)->firstline = newline;
      }
    }
    else if(0 < diff)
    {
      temp = *node;
      wordloc = addword(&temp->left, word, line);
    }
    else
    {
      temp = *node;
      wordloc = addword(&temp->right, word, line);
    }
  }
 }

 if(wordloc == NULL)
 {
   deleteword(node);
 }

 return wordloc;
}

/* We can't use strchr because it's not yet been discussed, so we'll
 * write our own instead.
 */
char *char_in_string(char *s, int c)
{
 char *p = NULL;

 /* if there's no data, we'll stop */
 if(s != NULL)
 {
   if(c != '\0')
   {
     while(*s != '\0' && *s != c)
     {
       ++s;
     }
     if(*s == c)
```

```
    {
      p = s;
    }
  }
 }

 return p;
}

/* We can't use strtok because it hasn't been discussed in the text
 * yet, so we'll write our own.
 * To minimise hassle at the user end, let's modify the user's pointer
 * to s, so that we can just call this thing in a simple loop.
 */
char *tokenise(char **s, char *delims)
{
 char *p = NULL;
 char *q = NULL;

 if(s != NULL && *s != '\0' && delims != NULL)
 {
  /* pass over leading delimiters */
  while(NULL != char_in_string(delims, **s))
  {
    ++*s;
  }
  if(**s != '\0')
  {
    q = *s + 1;
    p = *s;
    while(*q != '\0' && NULL == char_in_string(delims, *q))
    {
      ++q;
    }

    *s = q + (*q != '\0');
    *q = '\0';
  }
 }

 return p;
}
```

```
/* return zero if this word is not a noise word,
 * or non-zero if it is a noise word
 */

int NoiseWord(char *s)
{
  int found = 0;
  int giveup = 0;

  char *list[] =
  {
    "a",
    "an",
    "and",
    "be",
    "but",
    "by",
    "he",
    "I",
    "is",
    "it",
    "off",
    "on",
    "she",
    "so",
    "the",
    "they",
    "you"
  };
  int top = sizeof list / sizeof list[0] - 1;

  int bottom = 0;

  int guess = top / 2;

  int diff = 0;

  if(s != NULL)
  {
    while(!found && !giveup)
    {
      diff = i_strcmp(list[guess], s);
      if(0 == diff)
      {
```

```
      found = 1;
    }
    else if(0 < diff)
    {
      top = guess - 1;
    }
    else
    {
      bottom = guess + 1;
    }
    if(top < bottom)
    {
      giveup = 1;
    }
    else
    {
      guess = (top + bottom) / 2;
    }
  }
 }

 return found;
}

/*
 * Argh! We can't use fgets()! It's not discussed until page 164.
 * Oh well... time to roll our own again...
 */

char *GetLine(char *s, int n, FILE *fp)
{
 int c = 0;
 int done = 0;
 char *p = s;

 while(!done && --n > 0 && (c = getc(fp)) != EOF)
 {
  if((*p++ = c) == '\n')
  {
   done = 1;
  }
 }

 *p = '\0';
```

```
  if(EOF == c && p == s)
  {
    p = NULL;
  }
  else
  {
    p = s;
  }

  return p;
}

/*
 * Ideally, we'd use a clever GetLine function which expanded its
 * buffer dynamically to cope with large lines. Since we can't use
 * realloc, and because other solutions would require quite hefty
 * engineering, we'll adopt a simple solution - a big buffer.
 *
 * Note: making the buffer static will help matters on some
 * primitive systems which don't reserve much storage for
 * automatic variables, and shouldn't break anything anywhere.
 *
 */

#define MAXLINE 8192

int main(void)
{
  static char buffer[MAXLINE] = {0};
  char *s = NULL;
  char *word = NULL;
  int line = 0;
  int giveup = 0;
  struct wordtree *tree = NULL;

  char *delims = " \t\n\r\a\f\v!\"%^&*()_=+{}[]\\|/,.<>:;#~?";

  while(!giveup && GetLine(buffer, sizeof buffer, stdin) != NULL)
  {
    ++line;
    s = buffer;
    while(!giveup && (word = tokenise(&s, delims)) != NULL)
    {
```

```
      if(!NoiseWord(word))
      {
        if(NULL == addword(&tree, word, line))
        {
          printf("Error adding data into memory. Giving up.\n");
          giveup = 1;
        }
      }
    }
  }

  if(!giveup)
  {
    printf("%18s  Line Numbers\n", "Word");
    printtree(tree);
  }

  deleteword(&tree);

  return 0;
}
```

Answer to Exercise 6-4, page 143

Write a program that prints the distinct words in its input sorted into decreasing order of frequency of occurrence. Precede each word by its count.

Bryan's solution is, as far as I can tell, Category 1 only because he uses `EXIT_SUCCESS` and `EXIT_FAILURE` .

```
/*

  Chapter 6. Structures

        Write a program that prints out the distinct words in its
        input sorted into decreasing order of frequency of occurrence.
        Precede each word by its count.

  Author: Bryan Williams

*/

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

```c
#include <string.h>

#include <assert.h>


typedef struct WORD
{
  char *Word;
  size_t Count;
  struct WORD *Left;
  struct WORD *Right;
} WORD;


/*
  Assumptions: input is on stdin, output to stdout.

  Plan: read the words into a tree, keeping a count of how many we have,
       allocate an array big enough to hold Treecount (WORD *)'s
       walk the tree to populate the array.
       qsort the array, based on size.
       printf the array
       free the array
       free the tree
       free tibet (optional)
       free international shipping!
*/

#define SUCCESS                  0
#define CANNOT_MALLOC_WORDARRAY     1
#define NO_WORDS_ON_INPUT          2
#define NO_MEMORY_FOR_WORDNODE      3
#define NO_MEMORY_FOR_WORD         4


#define NONALPHA "1234567890
\v\f\n\t\r+=-*/\\,.;:'#~?<>|{}[]`!\"£$%^&()"

int ReadInputToTree(WORD **DestTree, size_t *Treecount, FILE *Input);
int AddToTree(WORD **DestTree, size_t *Treecount, char *Word);
int WalkTree(WORD **DestArray, WORD *Word);
int CompareCounts(const void *vWord1, const void *vWord2);
int OutputWords(FILE *Dest, size_t Count, WORD **WordArray);
void FreeTree(WORD *W);
```

```c
char *dupstr(char *s);


int main(void)
{
  int Status = SUCCESS;
  WORD *Words = NULL;
  size_t Treecount = 0;
  WORD **WordArray = NULL;

  /* Read the words on stdin into a tree */
  if(SUCCESS == Status)
  {
    Status = ReadInputToTree(&Words, &Treecount, stdin);
  }

  /* Sanity check for no sensible input */
  if(SUCCESS == Status)
  {
    if(0 == Treecount)
    {
      Status = NO_WORDS_ON_INPUT;
    }
  }

  /* allocate a sufficiently large array */
  if(SUCCESS == Status)
  {
     WordArray = malloc(Treecount * sizeof *WordArray);
     if(NULL == WordArray)
     {
       Status = CANNOT_MALLOC_WORDARRAY;
     }
  }

  /* Walk the tree into the array */
  if(SUCCESS == Status)
  {
    Status = WalkTree(WordArray, Words);
  }

  /* qsort the array */
  if(SUCCESS == Status)
  {
```

```
    qsort(WordArray, Treecount, sizeof *WordArray, CompareCounts);
  }

  /* walk down the WordArray outputting the values */
  if(SUCCESS == Status)
  {
    Status = OutputWords(stdout, Treecount, WordArray);
  }

  /* free the word array */
  if(NULL != WordArray)
  {
    free(WordArray);
    WordArray = NULL;
  }

  /* and free the tree memory */
  if(NULL != Words)
  {
    FreeTree(Words);
    Words = NULL;
  }

  /* Error report and we are finshed */
  if(SUCCESS != Status)
  {
    fprintf(stderr, "Program failed with code %d\n", Status);
  }
  return (SUCCESS == Status ? EXIT_SUCCESS : EXIT_FAILURE);
}



void FreeTree(WORD *W)
{
  if(NULL != W)
  {
    if(NULL != W->Word)
    {
      free(W->Word);
      W->Word = NULL;
    }
    if(NULL != W->Left)
```

```
    {
      FreeTree(W->Left);
      W->Left = NULL;
    }
    if(NULL != W->Right)
    {
      FreeTree(W->Right);
      W->Right = NULL;
    }
  }
}


int AddToTree(WORD **DestTree, size_t *Treecount, char *Word)
{
  int Status = SUCCESS;
  int CompResult = 0;

  /* safety check */
  assert(NULL != DestTree);
  assert(NULL != Treecount);
  assert(NULL != Word);

  /* ok, either *DestTree is NULL or it isn't (deep huh?) */
  if(NULL == *DestTree)  /* this is the place to add it then */
  {
    *DestTree = malloc(sizeof **DestTree);
    if(NULL == *DestTree)
    {
      /* horrible - we're out of memory */
      Status = NO_MEMORY_FOR_WORDNODE;
    }
    else
    {
      (*DestTree)->Left = NULL;
      (*DestTree)->Right = NULL;
      (*DestTree)->Count = 1;
      (*DestTree)->Word = dupstr(Word);
      if(NULL == (*DestTree)->Word)
      {
        /* even more horrible - we've run out of memory in the middle */
        Status = NO_MEMORY_FOR_WORD;
        free(*DestTree);
        *DestTree = NULL;
```

```
      }
      else
      {
        /* everything was successful, add one to the tree nodes count */
        ++*Treecount;
      }
    }
  }
  else  /* we need to make a decision */
  {
    CompResult = strcmp(Word, (*DestTree)->Word);
    if(0 < CompResult)
    {
      Status = AddToTree(&(*DestTree)->Left, Treecount, Word);
    }
    else if(0 > CompResult)
    {
      Status = AddToTree(&(*DestTree)->Left, Treecount, Word);
    }
    else
    {
      /* add one to the count - this is the same node */
      ++(*DestTree)->Count;
    }
  }  /* end of else we need to make a decision */

  return Status;
}


int ReadInputToTree(WORD **DestTree, size_t *Treecount, FILE *Input)
{
  int Status = SUCCESS;
  char Buf[8192] = {0};
  char *Word = NULL;

  /* safety check */
  assert(NULL != DestTree);
  assert(NULL != Treecount);
  assert(NULL != Input);

  /* for every line */
  while(NULL != fgets(Buf, sizeof Buf, Input))
  {
```

```
    /* strtok the input to get only alpha character words */
    Word = strtok(Buf, NONALPHA);
    while(SUCCESS == Status && NULL != Word)
    {
      /* deal with this word by adding it to the tree */
      Status = AddToTree(DestTree, Treecount, Word);

      /* next word */
      if(SUCCESS == Status)
      {
        Word = strtok(NULL, NONALPHA);
      }
    }
  }

  return Status;
}




int WalkTree(WORD **DestArray, WORD *Word)
{
  int Status = SUCCESS;
  static WORD **Write = NULL;

  /* safety check */
  assert(NULL != Word);

  /* store the starting point if this is the first call */
  if(NULL != DestArray)
  {
    Write = DestArray;
  }

  /* Now add this node and it's kids */
  if(NULL != Word)
  {
    *Write = Word;
    ++Write;
    if(NULL != Word->Left)
    {
      Status = WalkTree(NULL, Word->Left);
    }
```

```
    if(NULL != Word->Right)
    {
      Status = WalkTree(NULL, Word->Right);
    }
  }

  return Status;
}


/*
   CompareCounts is called by qsort. This means that it gets pointers to
the
   data items being compared. In this case the data items are pointers
too.
*/
int CompareCounts(const void *vWord1, const void *vWord2)
{
  int Result = 0;
  WORD * const *Word1 = vWord1;
  WORD * const *Word2 = vWord2;

  assert(NULL != vWord1);
  assert(NULL != vWord2);

  /* ensure the result is either 1, 0 or -1 */
  if((*Word1)->Count < (*Word2)->Count)
  {
    Result = 1;
  }
  else if((*Word1)->Count > (*Word2)->Count)
  {
    Result = -1;
  }
  else
  {
    Result = 0;
  }

  return Result;
}


int OutputWords(FILE *Dest, size_t Count, WORD **WordArray)
```

```
{
  int Status = SUCCESS;
  size_t Pos = 0;

  /* safety check */
  assert(NULL != Dest);
  assert(NULL != WordArray);

  /* Print a header */
  fprintf(Dest, "Total Words : %lu\n", (unsigned long)Count);

  /* Print the words in descending order */
  while(SUCCESS == Status && Pos < Count)
  {
    fprintf(Dest, "%10lu %s\n", (unsigned long)WordArray[Pos]->Count,
WordArray[Pos]->Word);
    ++Pos;
  }

  return Status;
}


/*
    dupstr: duplicate a string
*/
char *dupstr(char *s)
{
  char *Result = NULL;
  size_t slen = 0;

  /* sanity check */
  assert(NULL != s);

  /* get string length */
  slen = strlen(s);

  /* allocate enough storage */
  Result = malloc(slen + 1);

  /* populate string */
  if(NULL != Result)
  {
    memcpy(Result, s, slen);
```

```
    *(Result + slen) = '\0';
  }

  return Result;
}
```

Answer to Exercise 6-5, page 145

Write a function `undef` that will remove a name and definition from the table maintained by `lookup` and `install`.

```
int undef(char * name) {
    struct nlist * np1, * np2;

    if ((np1 = lookup(name)) == NULL)  /*  name not found  */
        return 1;

    for ( np1 = np2 = hashtab[hash(name)]; np1 != NULL;
          np2 = np1, np1 = np1->next ) {
        if ( strcmp(name, np1->name) == 0 ) {  /*  name found  */

            /*  Remove node from list  */

            if ( np1 == np2 )
                hashtab[hash(name)] = np1->next;
            else
                np2->next = np1->next;

            /*  Free memory  */

            free(np1->name);
            free(np1->defn);
            free(np1);

            return 0;
        }
    }

    return 1;  /*  name not found  */
}
```

Gregory Pietsch's solution

```
void undef(char *s)
{
    struct nlist *np1, *np2;
    unsigned hashval = hash(s);

    for (np1 = hashtab[hashval], np2 = NULL;
         np1 != NULL;
         np2 = np1, np1 = np1->next)
        if (strcmp(s, np1->name) == 0) {
            /* found a match */
            free(np1->name);
            free(np1->defn);
            if (np2 == NULL)
                /* at the beginning? */
                hashtab[hashval] = np1->next;
            else
                /* in the middle or at the end? */
                np2->next = np1->next;
            free(np1);
            return;
        }
}
```

Answer to Exercise 7-1, page 153

Write a program that converts upper case to lower or lower case to upper, depending on the name it is invoked with, as found in `argv[0]`.

```
/* This program converts its input to upper case
 * (if argv[0] begins with U or u) or lower case.
 * If argc is 0, it prints an error and quits.
 */

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


int main(int argc, char **argv)
{
```

```
  int (*convcase[2])(int) = {toupper, tolower};
  int func;
  int result = EXIT_SUCCESS;

  int ch;

  if(argc > 0)
  {
    if(toupper((unsigned char)argv[0][0]) == 'U')
    {
      func = 0;
    }
    else
    {
      func = 1;
    }

    while((ch = getchar()) != EOF)
    {
      ch = (*convcase[func])((unsigned char)ch);
      putchar(ch);
    }
  }
  else
  {
    fprintf(stderr, "Unknown name. Can't decide what to do.\n");
    result = EXIT_FAILURE;
  }

  return result;
}
```

Here's a category 1 solution from Bryan Williams...

```
/*

  Exercise 7-1. Write a program that converts upper case to lower case
or lower case to upper,
              depending on the name it is invoked with, as found in argv[0].
```

```
  Assumptions: The program should read from stdin, until EOF, converting
the output to stdout
             appropriately.

             The correct outputs should be :

             Program Name              Output
             lower                    stdin with all caps converted to
lower case
             upper                    stdin with all lowercase
characters converted to uppercase
             [anything else]           helpful message explaining how to
use this

  Author : Bryan Williams

*/

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

#define SUCCESS         0
#define NO_ARGV0        1
#define BAD_NAME        2


int main(int argc, char *argv[])
{
  int ErrorStatus = SUCCESS;
  int (*convert)(int c) = NULL;
  int c = 0;

  /* check that there were any arguments */
  if(SUCCESS == ErrorStatus)
  {
    if(0 >= argc)
    {
      printf("Your environment has not provided a single argument for the
program name.\n");
      ErrorStatus = NO_ARGV0;
    }
  }
```

```
  /* check for valid names in the argv[0] string */
  if(SUCCESS == ErrorStatus)
  {
    if(0 == strcmp(argv[0], "lower"))
    {
      convert = tolower;
    }
    else if(0 == strcmp(argv[0], "upper"))
    {
      convert = toupper;
    }
    else
    {
      printf("This program performs two functions.\n");
      printf("If the executable is named lower then it converts all the
input on stdin to lowercase.\n");
      printf("If the executable is named upper then it converts all the
input on stdin to uppercase.\n");
      printf("As you have named it %s it prints this message.\n", argv[0]);
      ErrorStatus = BAD_NAME;
    }
  }

  /* ok so far, keep looping until EOF is encountered */
  if(SUCCESS == ErrorStatus)
  {
    while(EOF != (c = getchar()))
    {
      putchar((*convert)(c));
    }
  }

  /* and return what happened */
  return SUCCESS == ErrorStatus ? EXIT_SUCCESS : EXIT_FAILURE;
}
```

Answer to Exercise 7-2, page 155

Write a program that will print arbitrary input in a sensible way. As a minimum, it should print non-graphic characters in octal or hexadecimal according to local custom, and break long text lines.

```
/* Use -o for octal output, -x for hexadecimal
```

```
 */

#include <stdio.h>

#define OCTAL       8
#define HEXADECIMAL 16


void ProcessArgs(int argc, char *argv[], int *output)
{
  int i = 0;
  while(argc > 1)
  {
    --argc;
    if(argv[argc][0] == '-')
    {
      i = 1;
      while(argv[argc][i] != '\0')
      {
        if(argv[argc][i] == 'o')
        {
          *output = OCTAL;
        }
        else if(argv[argc][i] == 'x')
        {
          *output = HEXADECIMAL;
        }
        else
        {
          /* Quietly ignore unknown switches, because we don't want to
           * interfere with the program's output. Later on in the
           * chapter, the delights of fprintf(stderr, "yadayadayada\n")
           * are revealed, just too late for this exercise.
           */
        }
      ++i;
      }
    }
  }
}

int can_print(int ch)
{
```

```
  char *printable =
"abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ1234567890 !\"#%
&'()*+,-./:;<=>?[\\]^_{|}~\t\f\v\r\n";

  char *s;
  int found = 0;

  for(s = printable; !found && *s; s++)
  {
    if(*s == ch)
    {
      found = 1;
    }
  }

  return found;
}

int main(int argc, char *argv[])
{
  int split = 80;
  int output = HEXADECIMAL;
  int ch;
  int textrun = 0;
  int binaryrun = 0;
  char *format;
  int width = 0;

  ProcessArgs(argc, argv, &output);

  if(output == HEXADECIMAL)
  {
    format = "%02X ";
    width = 4;
  }
  else
  {
    format = "%3o ";
    width = 4;
  }

  while((ch = getchar()) != EOF)
  {
    if(can_print(ch))
```

```
    {
      if(binaryrun > 0)
      {
        putchar('\n');
        binaryrun = 0;
        textrun = 0;
      }
      putchar(ch);
      ++textrun;
      if(ch == '\n')
      {
        textrun = 0;
      }

      if(textrun == split)
      {
        putchar('\n');
        textrun = 0;
      }
    }
    else
    {
      if(textrun > 0 || binaryrun + width >= split)
      {
        printf("\nBinary stream: ");
        textrun = 0;
        binaryrun = 15;
      }
      printf(format, ch);
      binaryrun += width;
    }
  }

  putchar('\n');

  return 0;
}
```

Answer to Exercise 7-3, page 156

Revise `minprintf` to handle more of the other facilities of `printf` .

```
/* Gregory Pietsch - K&R2 Exercise 7-3 - 2001-01-28 gkp@flash.net */
```

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

/* minprintf:  minimal printf with variable argument list */
void minprintf(char *fmt, ...)
{
    va_list ap;
    char *p, *sval;
    int ival;
    double dval;
    unsigned uval;

    va_start(ap, fmt);    /* make ap point to the first unnamed arg */
    for (p = fmt; *p; p++) {
        if (*p != '%') {
            putchar(*p);
            continue;
        }
        switch (*++p) {
        case 'd':
        case 'i':
            ival = va_arg(ap, int);
            printf("%d", ival);
            break;
        case 'c':
            ival = va_arg(ap, int);
            putchar(ival);
            break;
        case 'u':
            uval = va_arg(ap, unsigned int);
            printf("%u", uval);
            break;
        case 'o':
            uval = va_arg(ap, unsigned int);
            printf("%o", uval);
            break;
        case 'x':
            uval = va_arg(ap, unsigned int);
            printf("%x", uval);
            break;
        case 'X':
            uval = va_arg(ap, unsigned int);
            printf("%X", uval);
            break;
```

```
        case 'e':
            dval = va_arg(ap, double);
            printf("%e", dval);
            break;
        case 'f':
            dval = va_arg(ap, double);
            printf("%f", dval);
            break;
        case 'g':
            dval = va_arg(ap, double);
            printf("%g", dval);
            break;
        case 's':
            for (sval = va_arg(ap, char *); *sval; sval++)
                putchar(*sval);
            break;
        default:
            putchar(*p);
            break;
        }
    }
    va_end(ap);
}

/* end of function */
```

Answer to Exercise 7-6, page 165

Write a program to compare two files, printing the first line where they differ.

Here's Rick's solution:

```
/*************************************************
  KnR 7-6
  --------
  Write a program to compare two files and print the
  first line where they differ.

  Author: Rick Dearman
  email: rick@ricken.demon.co.uk

  Note: This program prints ALL the lines that are
```

```
        different using the <> indicators used by
         the unix diff command. However this program
         will not cope with something as simple as a
         line being removed.

         In reality the program would be more useful
         if it searched forward for matching lines.
         This would be a better indicator of the simple
         removal of some lines.

         This has lead me to track down a version of the
         "diff" command available on GNU/Linux systems.
         for more information go to the web site at:
         www.gnu.org

*****************************************************/
#include <stdio.h>
#include <string.h>
#define MAXLINE 1000

void diff_line( char *lineone, char *linetwo, int linenumber )
{
  if(strcmp (lineone, linetwo) < 0 || strcmp (lineone, linetwo) > 0)
    printf( "%d<%s\n%d>%s\n", linenumber, lineone, linenumber, linetwo);
}

int main(int argc, char *argv[] )
{
  FILE *fp1, *fp2;
  char fp1_line[MAXLINE], fp2_line[MAXLINE];
  int i;

  if ( argc != 3 )
    {
      printf("differ fileone filetwo\n");
      exit(0);
    }

  fp1 = fopen( argv[1], "r" );
  if ( ! fp1 )
    {
      printf("Error opening file %s\n", argv[1]);
    }
```

```
  fp2 = fopen( argv[2], "r" );
  if ( ! fp2 )
    {
      printf("Error opening file %s\n", argv[2]);
    }
  i = 0;
  while ( (fgets(fp1_line, MAXLINE, fp1) != NULL)
          && (fgets(fp2_line, MAXLINE, fp2) != NULL))
  {
    diff_line( fp1_line, fp2_line, i );
    i++;
  }

  return 0;
}
```

and here's "flippant squirrel"'s solution:

```
/* Exercise 7-6 - write a program to compare two files, printing the first
line
 * where they differ
 *
 * Note : I amended this a bit...if a file is shorter than the other, but
is identical
 * up to that point, the program prints out "EOF" as the string that's
not equal.
 *
 */

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

#define BUFF_SIZE 1000

/* uses fgets, removes the '\n' at the end of the string if it exists */
char *safegets(char *buffer, int length, FILE *file)
{
       char *ptr;
```

```
	int len;

	if (buffer != NULL)
	{
		ptr = fgets(buffer, length, file);

		if (ptr != NULL)
		{
			len = strlen(buffer);

			if (len > 0)
			{
				if (buffer[len - 1] == '\n')
				{
					buffer[len - 1] = '\0';
				}
			}
		}

		return ptr;
	}

	return NULL;
}

int main(int argc, char *argv[])
{
	FILE *leftFile, *rightFile;
	char buff1[BUFF_SIZE], buff2[BUFF_SIZE];
	char *ptr1, *ptr2;
	unsigned long lineNum = 0;

	if (argc < 3)
	{
		fprintf(stderr, "Usage : 7_6 <path to file> <path to
file>\n");
		return 0;
	}

	if (!(leftFile = fopen(argv[1], "r")))
	{
		fprintf(stderr, "Couldn't open %s for reading\n", argv[1]);
		return 0;
	}
```

```
        if (!(rightFile = fopen(argv[2], "r")))
        {
                fprintf(stderr, "Couldn't open %s for reading\n", argv[2]);
                fclose(leftFile); /* RJH 10 Jul 2000 */
                return 0;
        }

        /* read through each file, line by line */
        ptr1 = safegets(buff1, BUFF_SIZE, leftFile);
        ptr2 = safegets(buff2, BUFF_SIZE, rightFile);
        ++lineNum;

        /* stop when either we've exhausted either file's data */
        while (ptr1 != NULL && ptr2 != NULL)
        {
                /* compare the two lines */
                if (strcmp(buff1, buff2) != 0)
                {
                        printf("Difference:\n");
                        printf("%lu\t\"%s\" != \"%s\"\n", lineNum, buff1,
buff2);
                        goto CleanUp;
                }

                ptr1 = safegets(buff1, BUFF_SIZE, leftFile);
                ptr2 = safegets(buff2, BUFF_SIZE, rightFile);
                ++lineNum;
        }

        /*
         * if one of the files ended prematurely, it definitely
         * isn't equivalent to the other
         */
        if (ptr1 != NULL && ptr2 == NULL)
        {
                printf("Difference:\n");
                printf("%lu\t\"%s\" != \"EOF\"\n", lineNum, buff1);
        }
        else if (ptr1 == NULL && ptr2 != NULL)
        {
                printf("Difference:\n");
                printf("%lu\t\"EOF\" != \"%s\"\n", lineNum, buff2);
        }
```

```
        else
        {
                printf("No differences\n");
        }

CleanUp:

        fclose(leftFile);
        fclose(rightFile);
        return EXIT_SUCCESS;
}
```

Answer to Exercise 7-8, page 165

Write a program to print a set of files, starting each new one on a new page, with a title and a running page count for each file.

```
/* K&R Exercise 7-8 */
/* Steven Huang */

/*
   Limitation:  This program doesn't wrap long lines.
*/

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

#define LINES_PER_PAGE 10
#define TRUE         1
#define FALSE        0

void print_file(char *file_name)
{
  FILE *f;
  int page_number = 1;
  int line_count;
```

```
  int c;
  int new_page = TRUE;

  assert(file_name != NULL);

  if ((f = fopen(file_name, "r")) != NULL) {
    while ((c = fgetc(f)) != EOF) {
      if (new_page) {
        /* print out the header */
        printf("[%s] page %d starts\n", file_name, page_number);
        new_page = FALSE;
        line_count = 1;
      }
      putchar(c);
      if (c == '\n' && ++line_count > LINES_PER_PAGE) {
        /* print out the footer */
        printf("[%s] page %d ends\n", file_name, page_number);
        /* skip another line so we can see it on screen */
        putchar('\n');
        new_page = TRUE;
        page_number++;
      }
    }
    if (!new_page) {
      /* file ended in the middle of a page, so we still need to
         print a footer */
      printf("[%s] page %d ends\n", file_name, page_number);
    }
    /* skip another line so we can see it on screen */
    putchar('\n');
    fclose(f);
  }
}

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

  if (argc < 2) {
    fputs("no files specified\n", stderr);
    return EXIT_FAILURE;
  }
  for (i = 1; i < argc; i++) {
    print_file(argv[i]);
```

```
  }
  return EXIT_SUCCESS;
}
```

Answer to Exercise 7-9, page 168

Functions like `isupper` can be implemented to save space or to save time. Explore both possibilities.

This question is best left to an essay rather than code, so here's my take: The easiest way to implement the eleven `is()` functions in C90's version of `<ctype.h>` is via a table lookup. If `UCHAR_MAX` is 255, then a table would take up around 514 8-bit bytes and still have room for five more `is()` functions. In modern programs, this is a miniscule expense of both space and time since a mere table lookup doesn't cost a whole lot (although space may be a priority for embedded systems). Additionally, since the `is()` functions of `<ctype.h>` are locale-dependent and therefore subject to locale-specific whims, a table could more easily be modified than modifying hard calculations. Consider the following three implementations of `isupper()` : Implementation #1:

```
int isupper(int c)
{
    return (c >= 'A' && c <= 'Z');
}
```

Implementation #2:

```
int isupper(int c)
{
    return (strchr("ABCDEFGHIJKLMNOPQRSTUVWXYZ", c) != NULL);
}
```

Implementation #3:

```
/* Presumably, _UP is a power of 2 and
 * _Ctype is a table
 */

int isupper(int c)
{
    return ((_Ctype[(unsigned char)c] & _UP) != 0);
}
```

Implementation #1 fails in `EBCDIC` and implementation #2 fails in a locale that adds more upperspace characters than the ones mentioned. Implementation #3, however, suggests that `_Ctype[]` can be modified to accommodate new uppercase characters.

Answer to Exercise 8-1, page 174

Ron Scott has also sent me a solution to this exercise. Once he has granted me permission to display it here, I will post it on this site.

Rewrite the program `cat` from Chapter 7 using `read` , `write` , `open` and `close` instead of their standard library equivalents. Perform experiments to determine the relative speeds of the two versions.

```
/*
  Andrew Tesker
  ucat.c
  a version of cat using UNIX system access
*/

#include <stdio.h>
#include <fcntl.h>
#define BUFSIZE 1024


int main(int argc, char *argv[])
{
  int fd1;
  void filecopy(int f, int t);

  if(argc == 1)
    filecopy(0, 1);

  else {
    while(--argc > 0)
      if(( fd1 = open(*++argv, O_RDONLY, 0)) == -1) {
         printf("unix cat: can't open %s\n", *argv);
         return 1;
      }
      else {
         filecopy(fd1, 1);
         close(fd1);
      }
  }

  return 0;
```

```
}

void filecopy(int from, int to)
{
  int n;
  char buf[BUFSIZE];

  while((n=read(from, buf, BUFSIZE)) > 0 )
    write(to, buf, n);
}
```

Answer to Exercise 8-3, page 179

Design and write `_flushbuf` , `fflush` , and `fclose` .

```
/* Editor's note: Gregory didn't supply a main() for this. Normally, in
these situations,
 * I'd supply one myself, so that you can easily run and test the code.
But, in this case,
 * I wouldn't know where to start! If anyone wants to fill the gap, please
let me know.
 * Thanks.
 *      RJH, 28 June 2000
 */

#include <stdio.h>
/* on p.176 */
#include "syscalls.h"
/* or stdlib.h */

/* _flushbuf - flush a buffer
 * According to the code on p. 176, _flushbuf
 * is what putc calls when the buffer is full.
 * EOF as the character causes everything to
 * be written -- I don't tack on the EOF.
 */
int _flushbuf(int c, FILE *f)
{
    int num_written, bufsize;
    unsigned char uc = c;

    if ((f->flag & (_WRITE|_EOF|_ERR)) != _WRITE)
        return EOF;
```

```
    if (f->base == NULL && ((f->flag & _UNBUF) == 0)) {
        /* no buffer yet */
        if ((f->base = malloc(BUFSIZ)) == NULL)
            /* couldn't allocate a buffer, so try unbuffered */
            f->flag |= _UNBUF;
        else {
            f->ptr = f->base;
            f->cnt = BUFSIZ - 1;
        }
    }
    if (f->flag & _UNBUF) {
        /* unbuffered write */
        f->ptr = f->base = NULL;
        f->cnt = 0;
        if (c == EOF)
            return EOF;
        num_written = write(f->fd, &uc, 1);
        bufsize = 1;
    } else {
        /* buffered write */
        if (c != EOF)
            f->ptr++ = uc;
        bufsize = (int)(f->ptr - f->base);
        num_written = write(f->fd, fp->base, bufsize);
        f->ptr = f->base;
        f->cnt = BUFSIZ - 1;
    }
    if (num_written == bufsize)
        return c;
    else {
        f->flag |= _ERR;
        return EOF;
    }
}

/* fflush */
int fflush(FILE *f)
{
    int retval;
    int i;

    retval = 0;
    if (f == NULL) {
        /* flush all output streams */
```

```
        for (i = 0; i < OPEN_MAX; i++) {
            if ((_iob[i]->flag & _WRITE) && (fflush(_iob[i]) == -1))
                retval = -1;
        }
    } else {
        if ((f->flag & _WRITE) == 0)
            return -1;
        _flushbuf(EOF, f);
        if (f->flag & _ERR)
            retval = -1;
    }
    return retval;
}

/* fclose */
int fclose(FILE *f)
{
    int fd;

    if (f == NULL)
        return -1;
    fd = f->fd;
    fflush(f);
    f->cnt = 0;
    f->ptr = NULL;
    if (f->base != NULL)
        free(f->base);
    f->base = NULL;
    f->flag = 0;
    f->fd = -1;
    return close(fd);
}
```

Answer to Exercise 8-4, page 179

The standard library function
`int fseek(FILE *fp, long offset, int origin)`
is identical to `lseek` *except that* `fp` *is a file pointer instead of a file descriptor and the return value is an* `int` *status, not a position. Write* `fseek` *. Make sure that your* `fseek` *coordinates properly with the buffering done for the other functions of the library.*

Here's Gregory's first solution:

```
/* Gregory Pietsch -- My category 0 solution to 8-4 */
```

```c
int fseek(FILE *f, long offset, int whence)
{
    if ((f->flag & _UNBUF) == 0 && base != NULL) {
        /* deal with buffering */
        if (f->flag & _WRITE) {
            /* writing, so flush buffer */
            fflush(f);  /* from 8-3 */
        } else if (f->flag & _READ) {
            /* reading, so trash buffer */
            f->cnt = 0;
            f->ptr = f->base;
        }
    }
    return (lseek(f->fd, offset, whence) < 0);
}
```

...and here's his second, which is considerably more comprehensive:

```c
/*

[The following solution is in the zip file as krx80401.c - RJH (ed.) ]

EXERCISE 8-4

I thought I'd improve 8-4 too.  I'm trying my best to get this as close
to ISO C as possible given the restrictions that I'm under.  (A real
implementation would have fsetpos() borrow some of the same code.)

*/

/* Gregory Pietsch -- My category 0 solution to 8-4 */

#define SEEK_SET 0
#define SEEK_CUR 1
#define SEEK_END 2

int fseek(FILE *f, long offset, int whence)
{
    int result;

    if ((f->flag & _UNBUF) == 0 && base != NULL) {
        /* deal with buffering */
```

```
        if (f->flag & _WRITE) {
            /* writing, so flush buffer */
            if (fflush(f))
                return EOF;  /* from 8-3 */
        } else if (f->flag & _READ) {
            /* reading, so trash buffer --
             * but I have to do some housekeeping first
             */
            if (whence == SEEK_CUR) {
                /* fix offset so that it's from the last
                 * character the user read (not the last
                 * character that was actually read)
                 */
                if (offset >= 0 && offset <= f->cnt) {
                    /* easy shortcut */
                    f->cnt -= offset;
                    f->ptr += offset;
                    f->flags &= ~_EOF; /* see below */
                    return 0;
                } else
                    offset -= f->cnt;
            }
            f->cnt = 0;
            f->ptr = f->base;
        }
    }
    result = (lseek(f->fd, offset, whence) < 0);
    if (result == 0)
        f->flags &= ~_EOF; /* if successful, clear EOF flag */
    return result;
}
```

Answer to Exercise 8-6, page 189

The standard library function `calloc(n,size)` returns a pointer to n objects of size `size` , with the storage initialized to zero. Write `calloc` , by calling `malloc` or by modifying it.

```
/*
    Exercise 8.6. The standard library function calloc(n, size) returns
a pointer to n objects
```

```
                of size size, with the storage initialised to zero. Write
calloc, by calling
                malloc or by modifying it.

   Author: Bryan Williams

*/

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

/*
  Decided to re-use malloc for this because :
        1) If the implementation of malloc and the memory management layer
changes, this will be ok.
        2) Code re-use is great.

*/
void *mycalloc(size_t nmemb, size_t size)
{
  void *Result = NULL;

  /* use malloc to get the memory */
  Result = malloc(nmemb * size);

  /* and clear the memory on successful allocation */
  if(NULL != Result)
  {
    memset(Result, 0x00, nmemb * size);
  }

  /* and return the result */
  return Result;
}

/* simple test driver, by RJH */

#include <stdio.h>

int main(void)
{
  int *p = NULL;
  int i = 0;
```

```
  p = mycalloc(100, sizeof *p);
  if(NULL == p)
  {
    printf("mycalloc returned NULL.\n");
  }
  else
  {
    for(i = 0; i < 100; i++)
    {
      printf("%08X ", p[i]);
      if(i % 8 == 7)
      {
         printf("\n");
      }
    }
    printf("\n");
    free(p);
  }

  return 0;
}
```