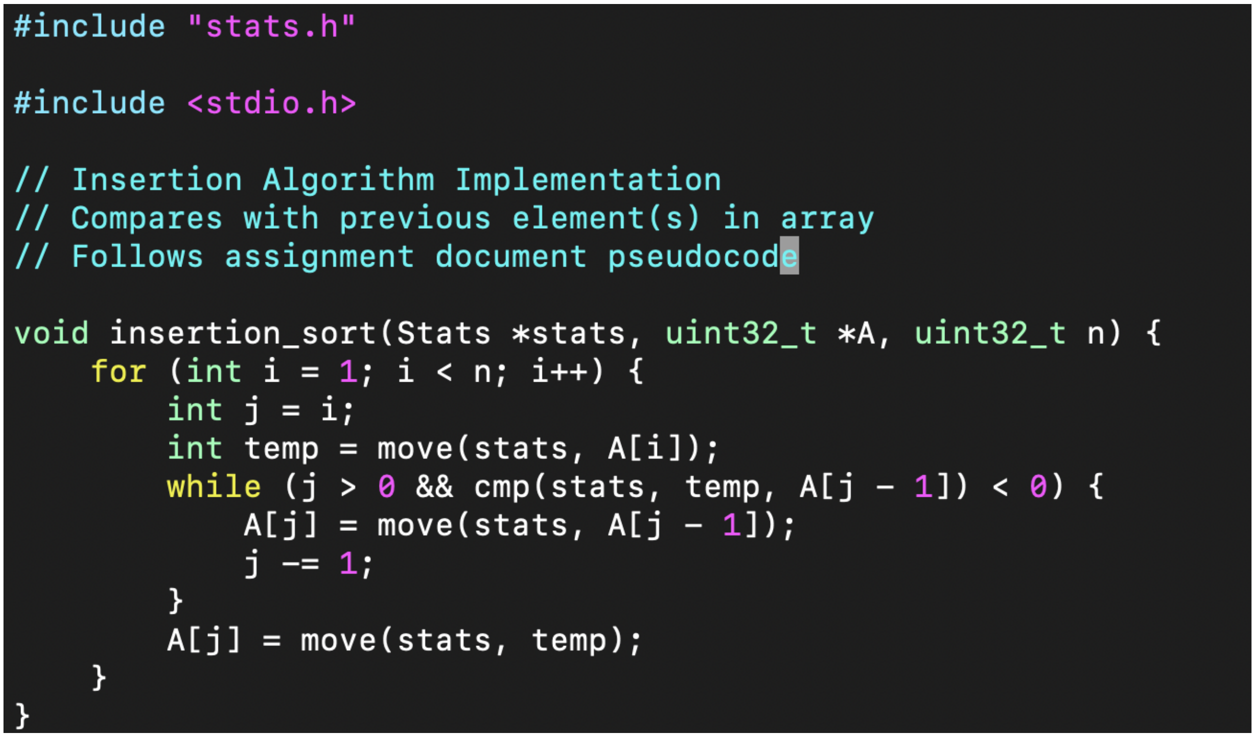
Assignment 3 - Sorting: Putting Your Affairs in Order

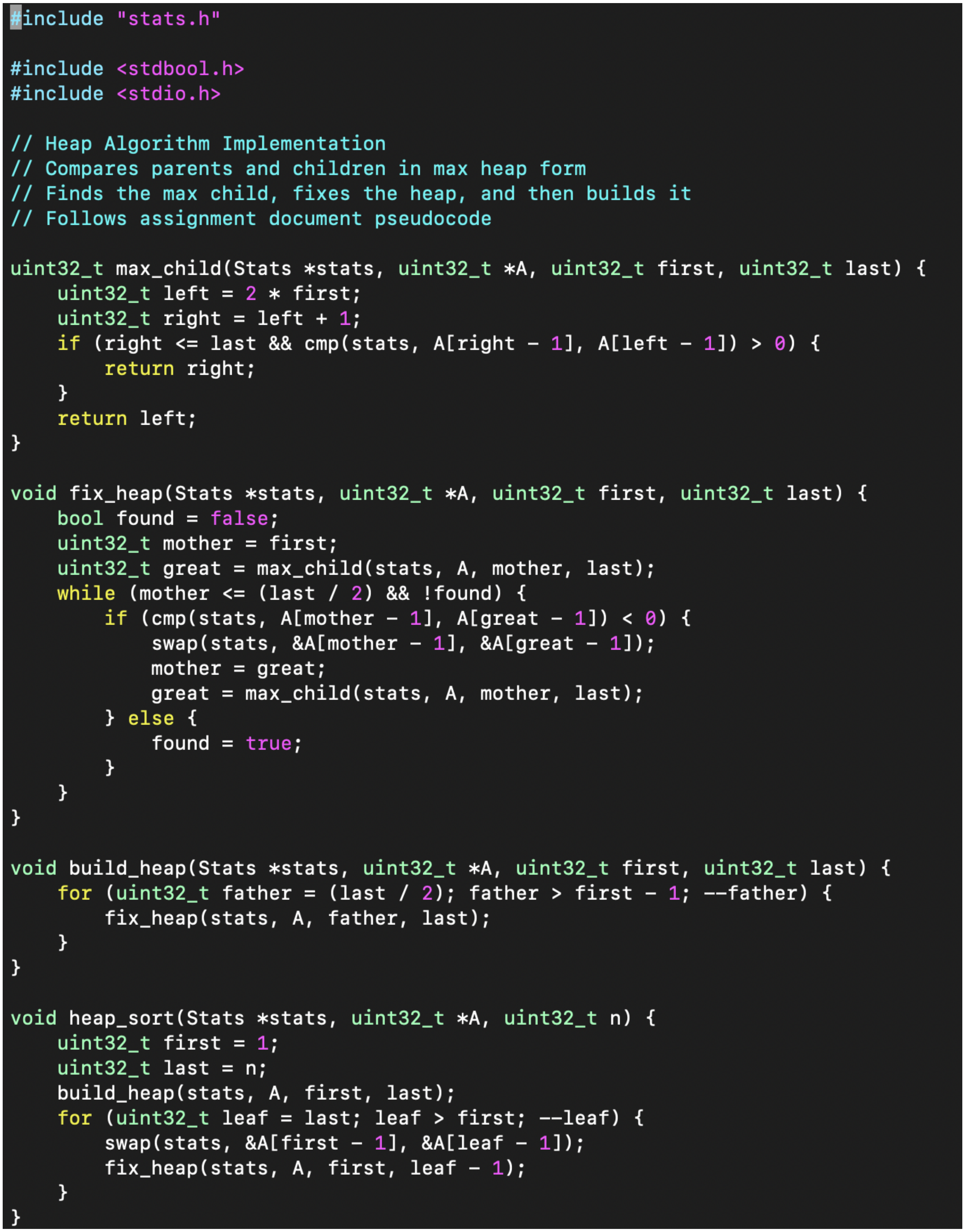
I learned that though there are many unique ways to sort an array, plenty of sorting algorithms involve similar techniques. For instance, insertion sort, which I found the most intuitive and straightforward, played a big role in shell sort, which I found really confusing and complex at first. Insertion sort is all about comparing the current element to its previous term. If the previous element is greater than the current element, then the two would move places, and this process would continue until the entire array is sorted in increasing order. Knowing that I had to implement a gap function and find a way to reduce this gap with every call in shell sort originally threw me off, but further contemplation helped me see how similar to insertion it is. In fact, everything following the for loops that keep track of the gap was the same exact process of comparing and moving elements. The gap function was essentially a way to go through the insertion process at a faster, more efficient rate. There are similarities between heap sort and quick sort as well. Both processes consider the array in smaller terms, whether it be by trees and nodes or smaller arrays. Both methods simplify the way we look at arrays (especially big ones) and help sort them efficiently.

insert.c



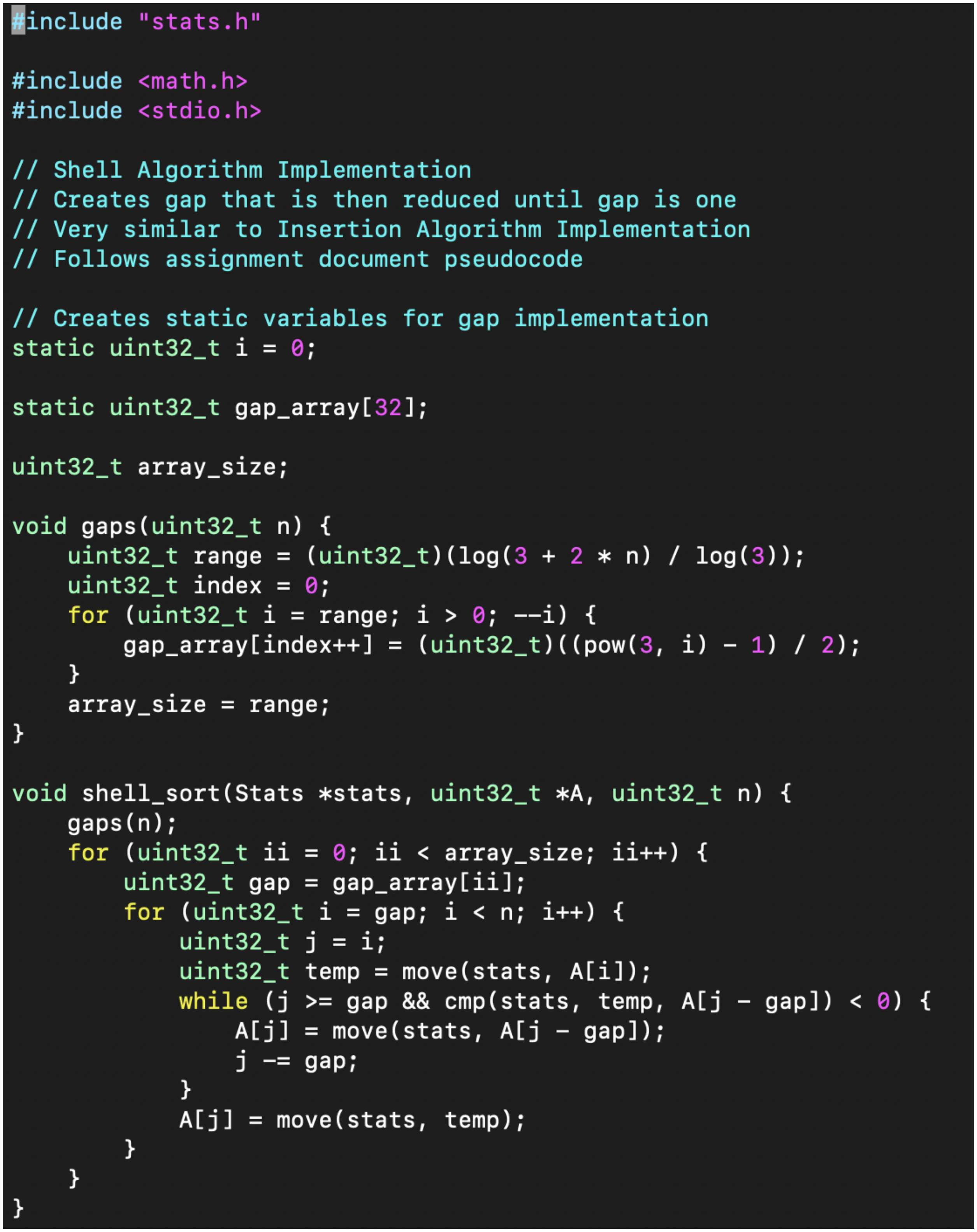
```
#include "stats.h"

#include <stdio.h>

// Insertion Algorithm Implementation
// Compares with previous element(s) in array
// Follows assignment document pseudocode

void insertion_sort(Stats *stats, uint32_t *A, uint32_t n) {
    for (int i = 1; i < n; i++) {
        int j = i;
        int temp = move(stats, A[i]);
        while (j > 0 && cmp(stats, temp, A[j - 1]) < 0) {
            A[j] = move(stats, A[j - 1]);
            j -= 1;
        }
        A[j] = move(stats, temp);
    }
}
```

heap.c



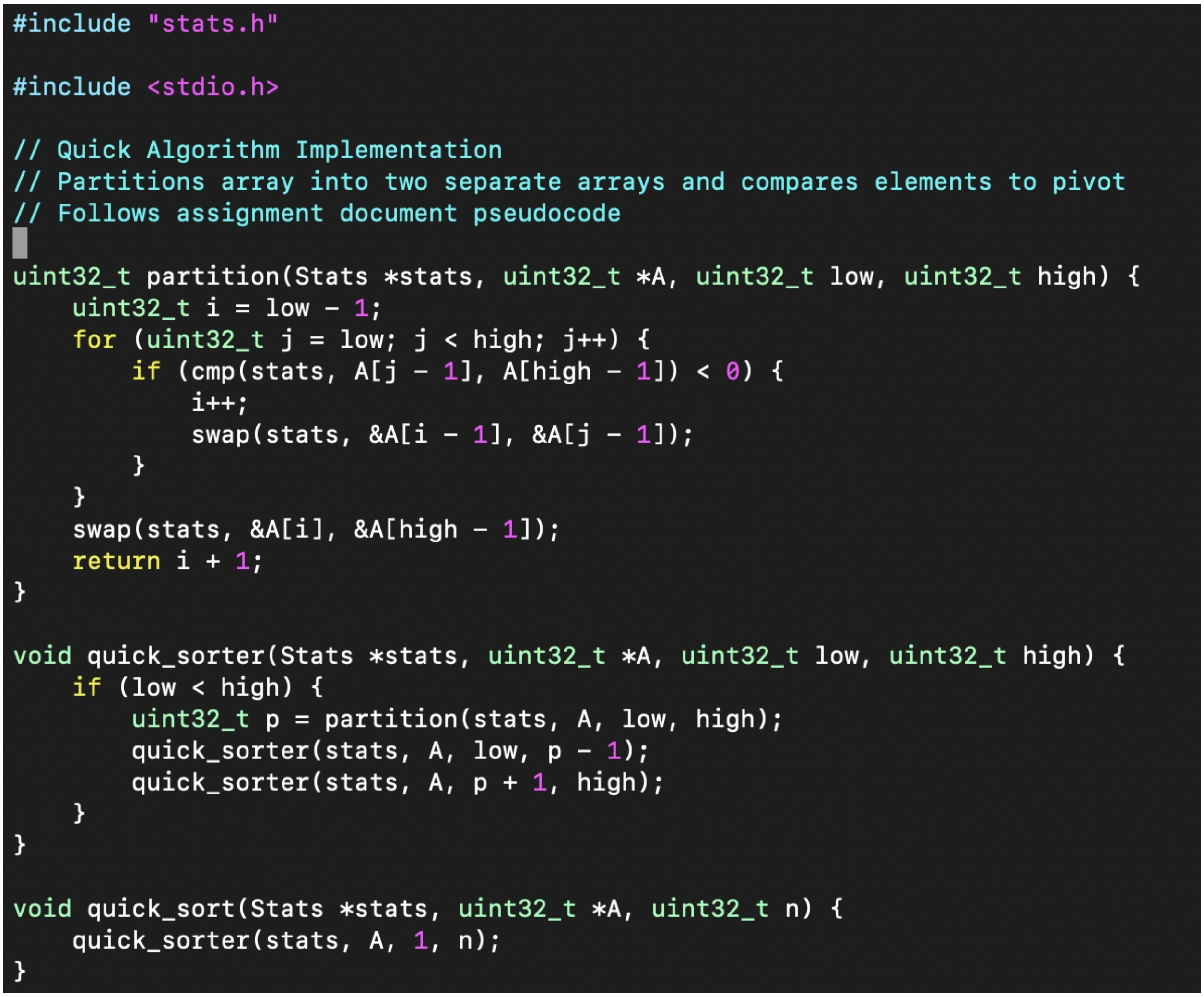
```
#include "stats.h"

#include <stdbool.h>
#include <stdio.h>

// Heap Algorithm Implementation
// Compares parents and children in max heap form
// Finds the max child, fixes the heap, and then builds it
// Follows assignment document pseudocode

uint32_t max_child(Stats *stats, uint32_t *A, uint32_t first, uint32_t last) {
    uint32_t left = 2 * first;
    uint32_t right = left + 1;
    if (right <= last && cmp(stats, A[right - 1], A[left - 1]) > 0) {
        return right;
    }
    return left;
}

void fix_heap(Stats *stats, uint32_t *A, uint32_t first, uint32_t last) {
    bool found = false;
    uint32_t mother = first;
    uint32_t great = max_child(stats, A, mother, last);
    while (mother <= (last / 2) && !found) {
        if (cmp(stats, A[mother - 1], A[great - 1]) < 0) {
            swap(stats, &A[mother - 1], &A[great - 1]);
            mother = great;
            great = max_child(stats, A, mother, last);
        } else {
            found = true;
        }
    }
}

void build_heap(Stats *stats, uint32_t *A, uint32_t first, uint32_t last) {
    for (uint32_t father = (last / 2); father > first - 1; --father) {
        fix_heap(stats, A, father, last);
    }
}

void heap_sort(Stats *stats, uint32_t *A, uint32_t n) {
    uint32_t first = 1;
    uint32_t last = n;
    build_heap(stats, A, first, last);
    for (uint32_t leaf = last; leaf > first; --leaf) {
        swap(stats, &A[first - 1], &A[leaf - 1]);
        fix_heap(stats, A, first, leaf - 1);
    }
}
```

shell.c



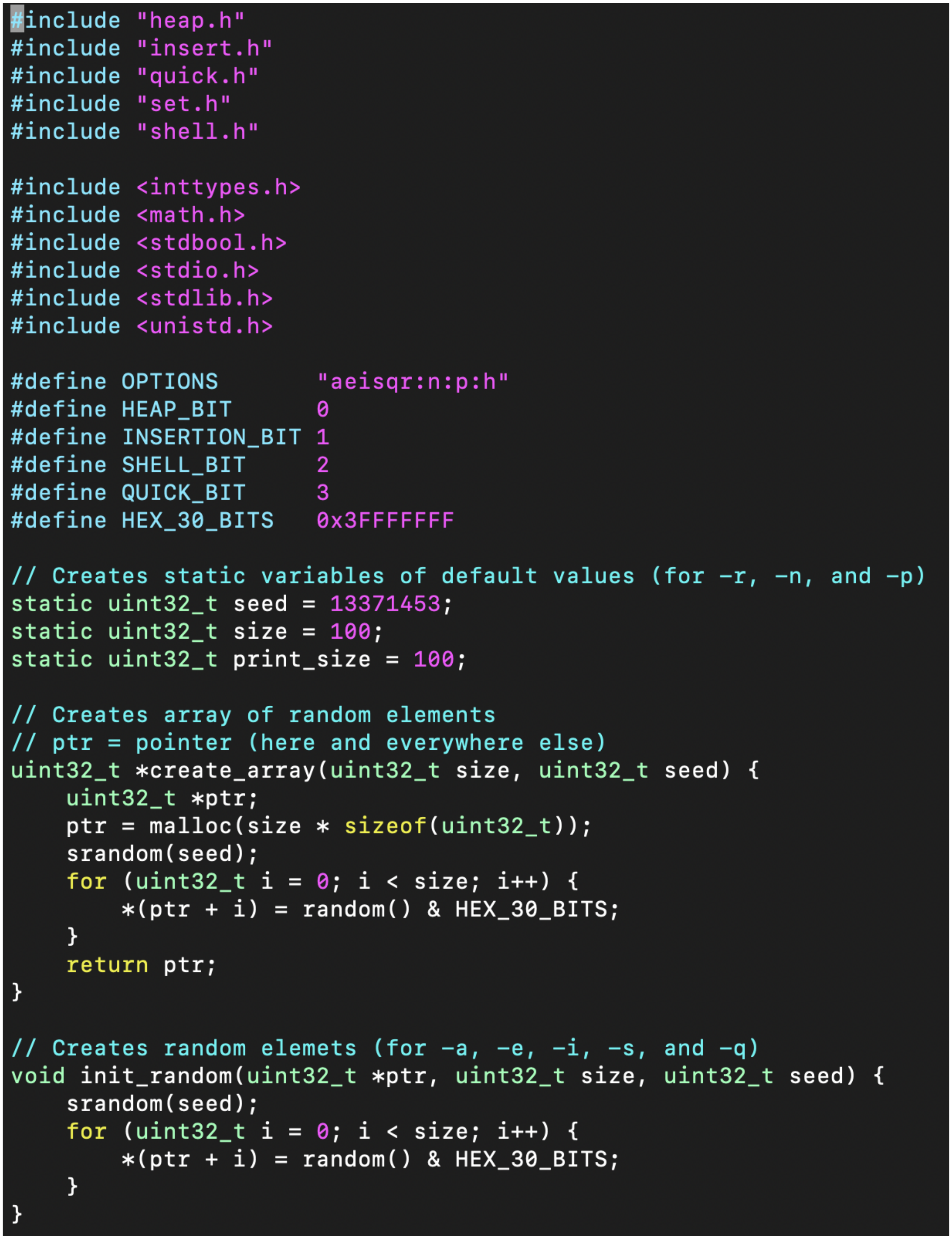
```c
#include "stats.h"

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

// Shell Algorithm Implementation
// Creates gap that is then reduced until gap is one
// Very similar to Insertion Algorithm Implementation
// Follows assignment document pseudocode

// Creates static variables for gap implementation
static uint32_t i = 0;

static uint32_t gap_array[32];

uint32_t array_size;

void gaps(uint32_t n) {
    uint32_t range = (uint32_t)(log(3 + 2 * n) / log(3));
    uint32_t index = 0;
    for (uint32_t i = range; i > 0; --i) {
        gap_array[index++] = (uint32_t)((pow(3, i) - 1) / 2);
    }
    array_size = range;
}

void shell_sort(Stats *stats, uint32_t *A, uint32_t n) {
    gaps(n);
    for (uint32_t ii = 0; ii < array_size; ii++) {
        uint32_t gap = gap_array[ii];
        for (uint32_t i = gap; i < n; i++) {
            uint32_t j = i;
            uint32_t temp = move(stats, A[i]);
            while (j >= gap && cmp(stats, temp, A[j - gap]) < 0) {
                A[j] = move(stats, A[j - gap]);
                j -= gap;
            }
            A[j] = move(stats, temp);
        }
    }
}
```

quick.c

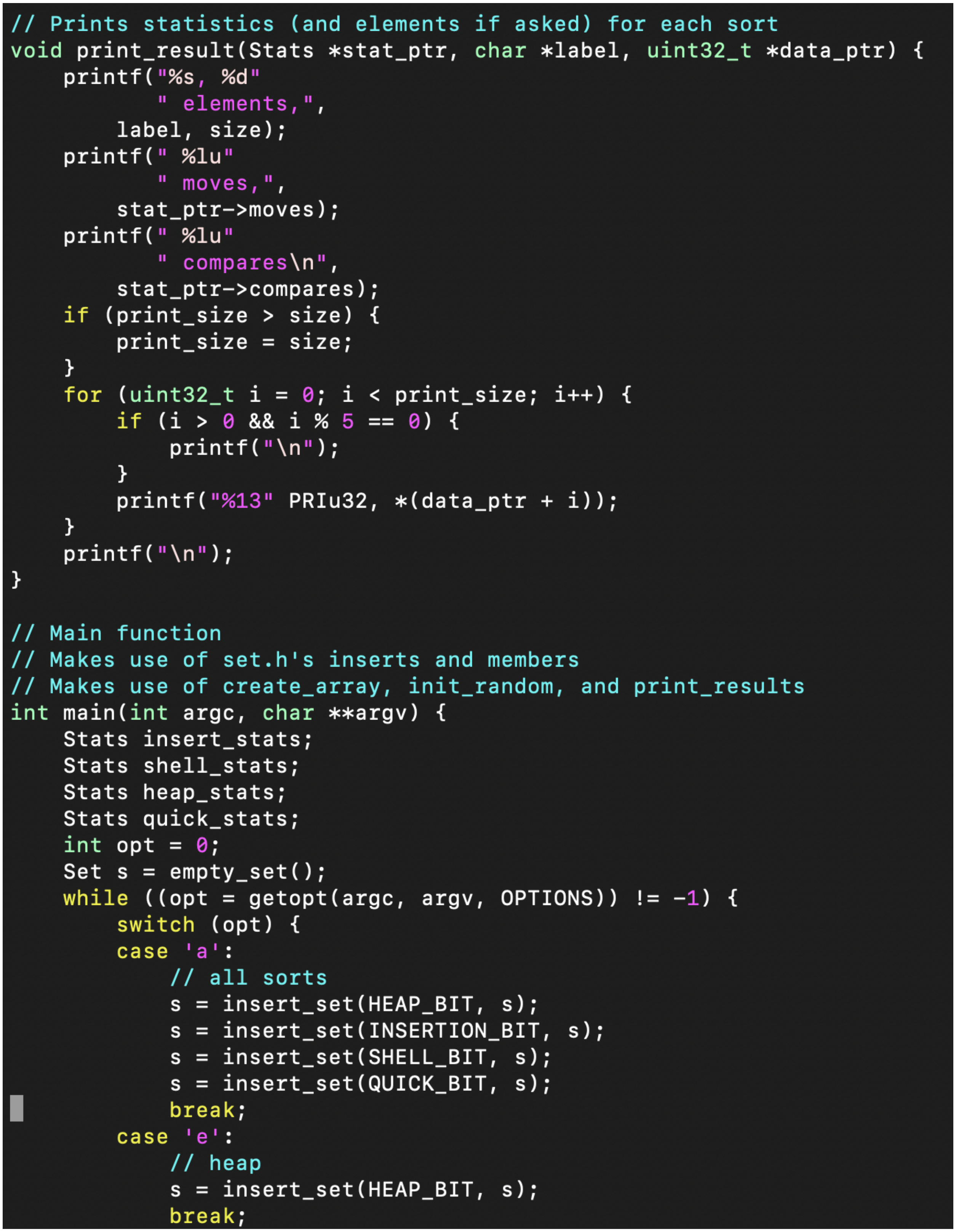


```
#include "stats.h"

#include <stdio.h>

// Quick Algorithm Implementation
// Partitions array into two separate arrays and compares elements to pivot
// Follows assignment document pseudocode

uint32_t partition(Stats *stats, uint32_t *A, uint32_t low, uint32_t high) {
    uint32_t i = low - 1;
    for (uint32_t j = low; j < high; j++) {
        if (cmp(stats, A[j - 1], A[high - 1]) < 0) {
            i++;
            swap(stats, &A[i - 1], &A[j - 1]);
        }
    }
    swap(stats, &A[i], &A[high - 1]);
    return i + 1;
}

void quick_sorter(Stats *stats, uint32_t *A, uint32_t low, uint32_t high) {
    if (low < high) {
        uint32_t p = partition(stats, A, low, high);
        quick_sorter(stats, A, low, p - 1);
        quick_sorter(stats, A, p + 1, high);
    }
}

void quick_sort(Stats *stats, uint32_t *A, uint32_t n) {
    quick_sorter(stats, A, 1, n);
}
```

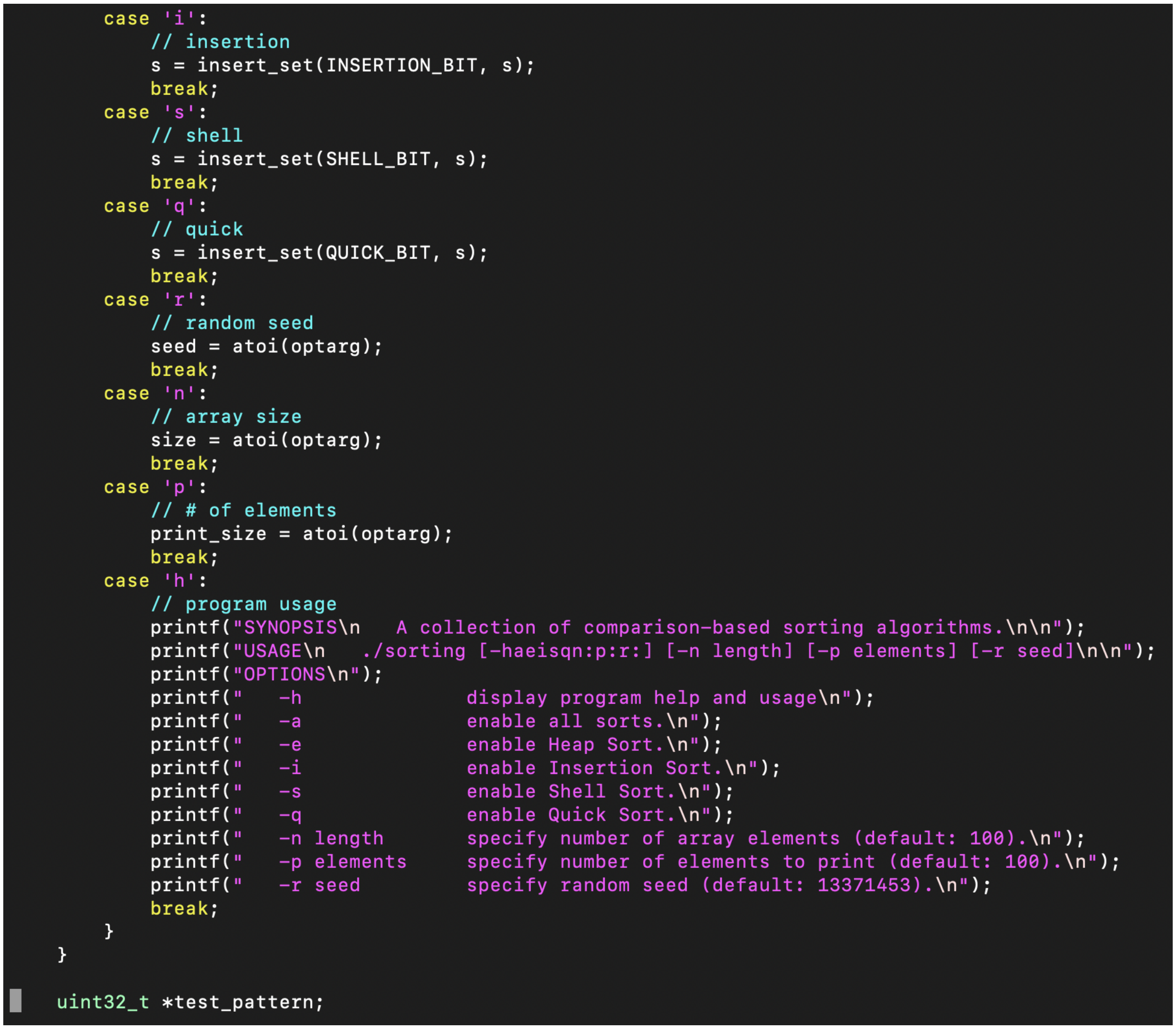
sorting.c



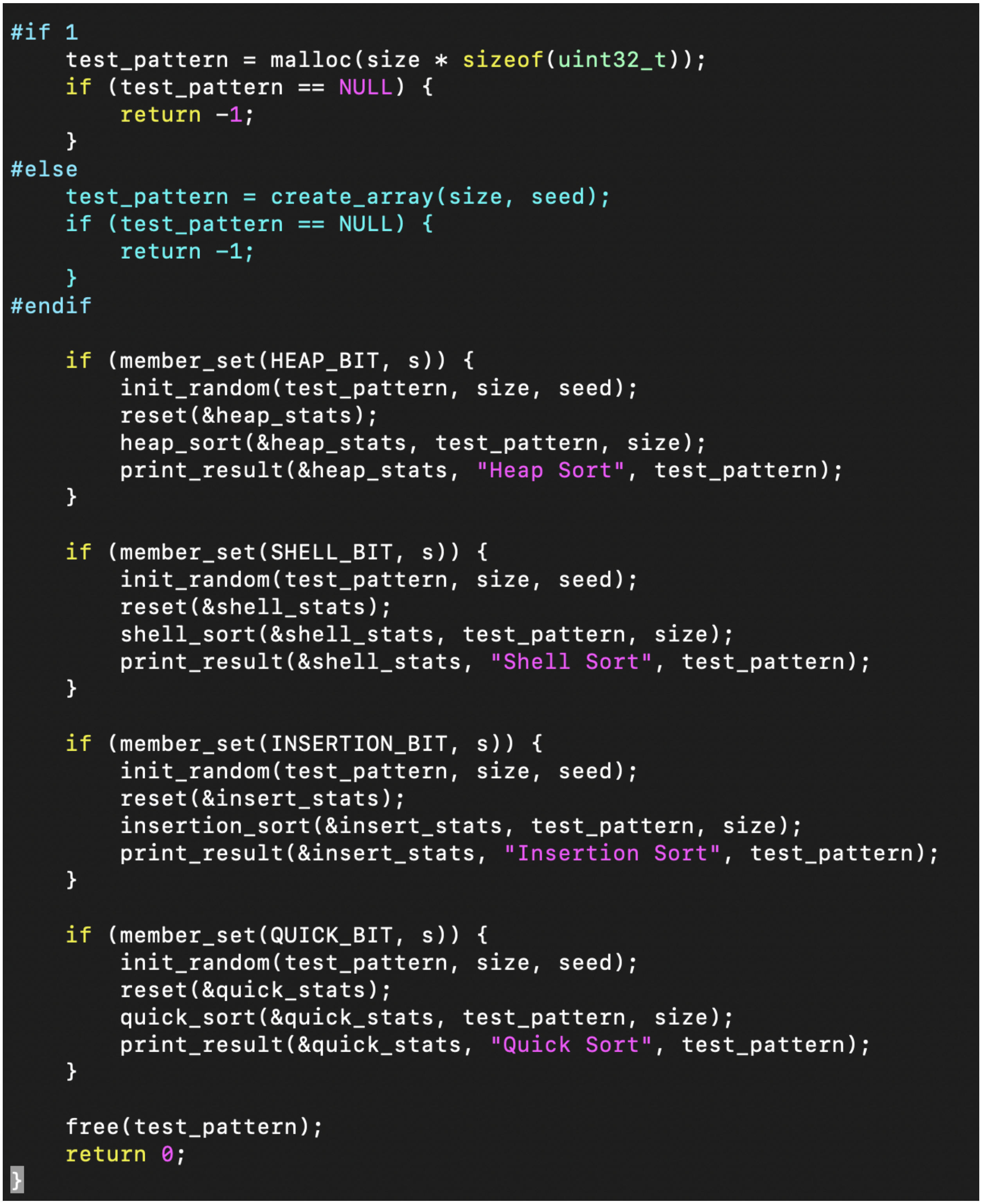
```
#include "heap.h"
#include "insert.h"
#include "quick.h"
#include "set.h"
#include "shell.h"

#include <inttypes.h>
#include <math.h>
#include <stdbool.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

#define OPTIONS       "aeisqr:n:p:h"
#define HEAP_BIT      0
#define INSERTION_BIT 1
#define SHELL_BIT     2
#define QUICK_BIT     3
#define HEX_30_BITS   0x3FFFFFFF

// Creates static variables of default values (for -r, -n, and -p)
static uint32_t seed = 13371453;
static uint32_t size = 100;
static uint32_t print_size = 100;

// Creates array of random elements
// ptr = pointer (here and everywhere else)
uint32_t *create_array(uint32_t size, uint32_t seed) {
    uint32_t *ptr;
    ptr = malloc(size * sizeof(uint32_t));
    srandom(seed);
    for (uint32_t i = 0; i < size; i++) {
        *(ptr + i) = random() & HEX_30_BITS;
    }
    return ptr;
}

// Creates random elemets (for -a, -e, -i, -s, and -q)
void init_random(uint32_t *ptr, uint32_t size, uint32_t seed) {
    srandom(seed);
    for (uint32_t i = 0; i < size; i++) {
        *(ptr + i) = random() & HEX_30_BITS;
    }
}
```



```c
// Prints statistics (and elements if asked) for each sort
void print_result(Stats *stat_ptr, char *label, uint32_t *data_ptr) {
    printf("%s, %d"
           " elements,",
        label, size);
    printf(" %lu"
           " moves,",
        stat_ptr->moves);
    printf(" %lu"
           " compares\n",
        stat_ptr->compares);
    if (print_size > size) {
        print_size = size;
    }
    for (uint32_t i = 0; i < print_size; i++) {
        if (i > 0 && i % 5 == 0) {
            printf("\n");
        }
        printf("%13" PRIu32, *(data_ptr + i));
    }
    printf("\n");
}

// Main function
// Makes use of set.h's inserts and members
// Makes use of create_array, init_random, and print_results
int main(int argc, char **argv) {
    Stats insert_stats;
    Stats shell_stats;
    Stats heap_stats;
    Stats quick_stats;
    int opt = 0;
    Set s = empty_set();
    while ((opt = getopt(argc, argv, OPTIONS)) != -1) {
        switch (opt) {
        case 'a':
            // all sorts
            s = insert_set(HEAP_BIT, s);
            s = insert_set(INSERTION_BIT, s);
            s = insert_set(SHELL_BIT, s);
            s = insert_set(QUICK_BIT, s);
            break;
        case 'e':
            // heap
            s = insert_set(HEAP_BIT, s);
            break;
```



```
        case 'i':
            // insertion
            s = insert_set(INSERTION_BIT, s);
            break;
        case 's':
            // shell
            s = insert_set(SHELL_BIT, s);
            break;
        case 'q':
            // quick
            s = insert_set(QUICK_BIT, s);
            break;
        case 'r':
            // random seed
            seed = atoi(optarg);
            break;
        case 'n':
            // array size
            size = atoi(optarg);
            break;
        case 'p':
            // # of elements
            print_size = atoi(optarg);
            break;
        case 'h':
            // program usage
            printf("SYNOPSIS\n   A collection of comparison-based sorting algorithms.\n\n");
            printf("USAGE\n   ./sorting [-haeisqn:p:r:] [-n length] [-p elements] [-r seed]\n\n");
            printf("OPTIONS\n");
            printf("   -h              display program help and usage\n");
            printf("   -a              enable all sorts.\n");
            printf("   -e              enable Heap Sort.\n");
            printf("   -i              enable Insertion Sort.\n");
            printf("   -s              enable Shell Sort.\n");
            printf("   -q              enable Quick Sort.\n");
            printf("   -n length       specify number of array elements (default: 100).\n");
            printf("   -p elements     specify number of elements to print (default: 100).\n");
            printf("   -r seed         specify random seed (default: 13371453).\n");
            break;
        }
    }

    uint32_t *test_pattern;
```



```
#if 1
    test_pattern = malloc(size * sizeof(uint32_t));
    if (test_pattern == NULL) {
        return -1;
    }
#else
    test_pattern = create_array(size, seed);
    if (test_pattern == NULL) {
        return -1;
    }
#endif

    if (member_set(HEAP_BIT, s)) {
        init_random(test_pattern, size, seed);
        reset(&heap_stats);
        heap_sort(&heap_stats, test_pattern, size);
        print_result(&heap_stats, "Heap Sort", test_pattern);
    }

    if (member_set(SHELL_BIT, s)) {
        init_random(test_pattern, size, seed);
        reset(&shell_stats);
        shell_sort(&shell_stats, test_pattern, size);
        print_result(&shell_stats, "Shell Sort", test_pattern);
    }

    if (member_set(INSERTION_BIT, s)) {
        init_random(test_pattern, size, seed);
        reset(&insert_stats);
        insertion_sort(&insert_stats, test_pattern, size);
        print_result(&insert_stats, "Insertion Sort", test_pattern);
    }

    if (member_set(QUICK_BIT, s)) {
        init_random(test_pattern, size, seed);
        reset(&quick_stats);
        quick_sort(&quick_stats, test_pattern, size);
        print_result(&quick_stats, "Quick Sort", test_pattern);
    }

    free(test_pattern);
    return 0;
}
```