

Notes

Introduction to Computer Science (CS50) on EdX

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Part I

General

Chapter 1

Computational Thinking, Scratch

1.1 Binary Number System

1.2 Algorithms

1.3 Time Complexity

1.4 Pseudocode

1.5 Scratch

This was only an introductory lecture. [Click here](#) for more details.

Chapter 2

C

2.1 Hello World

[ht!]

```
1  #include <stdio.h>
2
3  int main(void)
4  {
5      printf("Hello, World!\n");
6  }
```

Program 2.1: Hello World in C

Remark. Need to compile using a compiler like clang or gcc.

2.2 Input

[ht!]

```
1  #include <cs50.h>
2  #include <stdio.h>
3
4  int main(void)
5  {
6      string answer = get_string("What's your name?\n");
7      printf("Hello, %s!\n", answer);
8  }
```

Program 2.2: Hello User in C

Remark. In case of errors in compiling, start by trying to *fix* the first one, and so on.

Remark. Use `-lcs50` to link `cs50.h` header.

Remark. Use `make` to ease your life compiling!

2.3 Initialization

```
1 int counter = 0;
```

2.4 Increment

```
1 counter = counter + 1;
2 counter += 1;
3 counter++; // Syntactic Sugar
```

2.5 Conditionals

```
1 if (x < y)
2 {
3     printf("x is less than y!\n");
4 }
5 else if (x > y)
6 {
7     printf("x is greater than y!\n");
8 }
9 else // if (x == y)
10 {
11     printf("x is equal to y!\n");
12 }
```

2.6 Loops

2.6.1 While Loop

Infinite Loop

```
1 while(true)
2 {
3
4 }
```

Repeat

```
1 int i = 0;
2 while(i < 50)
```

```

3 {
4     printf("Hello World!\n");
5     i = i+1;
6 }

```

2.6.2 For Loop

```

1 for(int i = 0; i < 50; i += 1)
2 {
3     printf("Hello World!\n");
4 }

```

2.7 Additional Info

2.7.1 Datatypes

Some of these (like string) are implemented in `cs50.h` library.

- `bool`
- `char`
- `double`
- `float`
- `int`
- `long`
- `string`
- ...

2.7.2 Functions

They are implemented in `cs50.h` library.

- `get_char`
- `get_float`
- `get_double`

- `get_int`
- `get_long`
- `get_string`
- ...

2.7.3 Placeholders

- `%c` for `char`
- `%f` for `float`
- `%i` for `int`
- `%li` for `long`
- `%s` for `string`

2.7.4 Arithmetic Operations

- `+`
- `-`
- `*`
- `/`
- `%`

2.8 Examples

2.8.1 Arithmetic

[ht!]

```

1  #include <cs50.h>
2  #include <stdio.h>
3
4  int main(void)
5  {
6      int age = get_int("What's your age?\n");

```

```

7     // int days = age * 365;
8     // printf("You are atleast %i days old.\n", days);
9     printf("You are atleast %i days old.\n", age * 365);
10 }

```

Program 2.3: int.c

[ht!]

```

1  #include <cs50.h>
2  #include <stdio.h>
3
4  int main(void)
5  {
6      float price = get_float("What's the price?\n");
7      // printf("Your total is %f.\n", price * 1.18);
8      printf("Your total is %.2f.\n", price * 1.18);
9  }

```

Program 2.4: float.c

[ht!]

```

1  #include <cs50.h>
2  #include <stdio.h>
3
4  int main(void)
5  {
6      int n = get_int("n: ");
7
8      if (n % 2 == 0)
9      {
10         printf("even.\n");
11     }
12     else
13     {
14         printf("odd.\n");
15     }
16 }

```

Program 2.5: parity.c

2.8.2 Conditional

[ht!]

```
1  // Conditions and relational operators
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  int main(void)
7  {
8      // Prompt user for x
9      int x = get_int("x: ");
10
11     // Prompt user for y
12     int y = get_int("y: ");
13
14     // Compare x and y
15     if (x < y)
16     {
17         printf("x is less than y\n");
18     }
19     else if (x > y)
20     {
21         printf("x is greater than y\n");
22     }
23     else
24     {
25         printf("x is equal to y\n");
26     }
27 }
```

Program 2.6: conditions.c

2.8.3 Logical

[ht!]

```
1 // Logical operators
2 #include <cs50.h>
3 #include <stdio.h>
4 int main(void)
5 {
6     // Prompt user to agree
7     char c = get_char("Do you agree?\n");
8     // Check whether agreed
9     if (c == 'Y'  c == 'y')
10    {
11        printf("Agreed.\n");
12    }
13    else if (c == 'N'  c == 'n')
14    {
15        printf("Not agreed.\n");
16    }
17 }
```

Program 2.7: agree.c

2.8.4 Loop

[ht!]

```
1  // Opportunity for better design
2
3  #include <stdio.h>
4
5  int main(void)
6  {
7      printf("cough\n");
8      printf("cough\n");
9      printf("cough\n");
10 }
```

Program 2.8: cough0.c

[ht!]

```
1  // Better design
2
3  #include <stdio.h>
4
5  int main(void)
6  {
7      for (int i = 0; i < 3; i++)
8      {
9          printf("cough\n");
10     }
11 }
```

Program 2.9: cough1.c

2.8.5 Function

[ht!]

```
1  // Abstraction
2
3  #include <stdio.h>
4
5  void cough(void);
6
7  int main(void)
8  {
9      for (int i = 0; i < 3; i++)
10         {
11             cough();
12         }
13 }
14
15 // Cough once
16 void cough(void)
17 {
18     printf("cough\n");
19 }
```

Program 2.10: cough2.c

[ht!]

```
1  // Abstraction with parameterization
2
3  #include <stdio.h>
4
5  void cough(int n);
6
7  int main(void)
8  {
9      cough(3);
10 }
11
12 // Cough some number of times
13 void cough(int n)
14 {
15     for (int i = 0; i < n; i++)
```

```

16     {
17         printf("cough\n");
18     }
19 }

```

Program 2.11: cough3.c

[ht!]

```

1  // Abstraction and scope
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  int get_positive_int(void);
7
8  int main(void)
9  {
10     int i = get_positive_int();
11     printf("%i\n", i);
12 }
13
14 // Prompt user for positive integer
15 int get_positive_int(void)
16 {
17     int n;
18     do
19     {
20         n = get_int("Positive Integer: ");
21     }
22     while (n < 1);
23     return n;
24 }

```

Program 2.12: positive.c

[ht!]

```

1  // Prints a row of 4 question marks
2
3  #include <stdio.h>
4
5  int main(void)

```

```

6 {
7     printf("????\n");
8 }

```

Program 2.13: mario0.c

[ht!]

```

1  // Prints a row of n question marks with a loop
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  int main(void)
7  {
8      int n;
9      do
10     {
11         n = get_int("Width: ");
12     }
13     while (n < 1);
14     for (int i = 0; i < n; i++)
15     {
16         printf("?");
17     }
18     printf("\n");
19 }

```

Program 2.14: mario2.c

[ht!]

```

1  // Prints an n-by-n grid of bricks with a loop
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  int main(void)
7  {
8      int n;
9      do
10     {
11         n = get_int("Size: ");

```

```
12     }
13     while (n < 1);
14     for (int i = 0; i < n; i++)
15     {
16         for (int j = 0; j < n; j++)
17         {
18             printf("#");
19         }
20         printf("\n");
21     }
22 }
```

Program 2.15: mario8.c

2.9 Limitations

[ht!]

```
1 // Floating-point arithmetic with float
2
3 #include <cs50.h>
4 #include <stdio.h>
5
6 int main(void)
7 {
8     // Prompt user for x
9     float x = get_float("x: ");
10
11     // Prompt user for y
12     float y = get_float("y: ");
13
14     // Perform division
15     printf("x / y = %.50f\n", x / y);
16 }
```

Program 2.16: floats.c

[ht!]

```
1 // Integer overflow
2
3 #include <stdio.h>
4 #include <unistd.h>
5
6 int main(void)
7 {
8     // Iteratively double i
9     for (int i = 1; ; i *= 2)
10     {
11         printf("%i\n", i);
12         sleep(1);
13     }
14 }
```

Program 2.17: overflow.c

[Click here for more examples.](#)

Chapter 3

Arrays

3.1 Compiling

3.1.1 Preprocessing

Expansion/Inclusion of header files, macros, etc.

3.1.2 Compiling

C code → Assembly code.

3.1.3 Assembling

Assembly code → Machine code.

3.1.4 Linking

Linking all relevant files.

3.2 Debugging

- Can use `help50` to understand error msgs in this course.
- Can use (poor man's) `printf`.
- Can use `debug50` for proper debugging (in this course).

Remark. Use `style50` for styling your code.

3.3 Casting

[ht!]

```
1 // Prints ASCII codes
2
3 #include <stdio.h>
4
5 int main(void)
6 {
7     char c1 = 'H';
8     char c2 = 'I';
9     char c3 = '!';
10    printf("%i %i %i\n", c1, c2, c3);
11 }
```

Program 3.1: casting

3.4 Array

Follow through the following examples: [htbp!]

```
1 // Averages three numbers
2
3 #include <cs50.h>
4 #include <stdio.h>
5
6 int main(void)
7 {
8     // Scores
9     int score1 = 72;
10    int score2 = 73;
11    int score3 = 33;
12
13    // Print average
14    printf("Average: %i\n", (score1 + score2 + score3) / 3);
15 }
```

Program 3.2: scores0.c

[htbp!]

```

1  // Averages three numbers using an array
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  int main(void)
7  {
8      // Scores
9      int scores[3];
10     scores[0] = 72;
11     scores[1] = 73;
12     scores[2] = 33;
13
14     // Print average
15     printf("Average: %i\n", (scores[0] + scores[1] + scores[2])
16           - / 3);
17 }

```

Program 3.3: scores1.c

[htbp!]

```

1  // Averages three numbers using an array and a constant
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  const int N = 3;
7
8  int main(void)
9  {
10     // Scores
11     int scores[N];
12     scores[0] = 72;
13     scores[1] = 73;
14     scores[2] = 33;
15
16     // Print average
17     printf("Average: %i\n", (scores[0] + scores[1] + scores[2])
18           - / N);
19 }

```

Program 3.4: scores2.c

[htbp!]

```
1  // Averages numbers using a helper function
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  float average(int length, int array[]);
7
8  int main(void)
9  {
10     // Get number of scores
11     int n = get_int("Scores: ");
12
13     // Get scores
14     int scores[n];
15     for (int i = 0; i < n; i++)
16     {
17         scores[i] = get_int("Score %i: ", i + 1);
18     }
19
20     // Print average
21     printf("Average: %.1f\n", average(n, scores));
22 }
23
24 float average(int length, int array[])
25 {
26     int sum = 0;
27     for (int i = 0; i < length; i++)
28     {
29         sum += array[i];
30     }
31     return (float) sum / (float) length;
32 }
```

Program 3.5: scores3.c

3.5 String

string is just (or a little more) than an array of chars.

[!htbp]

```
1 // Stores names using an array
2
3 #include <cs50.h>
4 #include <stdio.h>
5 #include <string.h>
6
7 int main(void)
8 {
9     // Names
10    string names[4];
11    names[0] = "EMMA";
12    names[1] = "RODRIGO";
13    names[2] = "BRIAN";
14    names[3] = "DAVID";
15
16    // Print Emma's name
17    printf("%s\n", names[0]);
18    printf("%c%c%c%c\n", names[0][0], names[0][1], names[0][2],
19           ↪ names[0][3]);
20 }
```

Program 3.6: names.c

[!htbp]

```
1 // Prints string char by char, one per line
2
3 #include <cs50.h>
4 #include <stdio.h>
5
6 int main(void)
7 {
8     string s = get_string("Input: ");
9     printf("Output: ");
10    for (int i = 0; s[i] != '\0'; i++)
11    {
12        printf("%c", s[i]);
13    }
```

```

13     }
14     printf("\n");
15 }

```

Program 3.7: string0.c

[!htbp]

```

1  // Prints string char by char, one per line, using strlen
2
3  #include <cs50.h>
4  #include <stdio.h>
5  #include <string.h>
6
7  int main(void)
8  {
9      string s = get_string("Input: ");
10     printf("Output: ");
11     for (int i = 0; i < strlen(s); i++)
12     {
13         printf("%c", s[i]);
14     }
15     printf("\n");
16 }

```

Program 3.8: string1.c

[!htbp]

```

1  // Prints string char by char, one per line, using strlen,
2      remembering string's length
3
4  #include <cs50.h>
5  #include <stdio.h>
6  #include <string.h>
7
8  int main(void)
9  {
10     string s = get_string("Input: ");
11     printf("Output: ");
12     for (int i = 0, n = strlen(s); i < n; i++)
13     {
14         printf("%c", s[i]);
15     }
16 }

```

```

14     }
15     printf("\n");
16 }

```

Program 3.9: string2.c

[!htbp]

```

1  // Uppercases a string
2
3  #include <cs50.h>
4  #include <stdio.h>
5  #include <string.h>
6
7  int main(void)
8  {
9      string s = get_string("Before: ");
10     printf("After:  ");
11     for (int i = 0, n = strlen(s); i < n; i++)
12     {
13         if (s[i] >= 'a' && s[i] <= 'z')
14         {
15             printf("%c", s[i] - 32);
16         }
17         else
18         {
19             printf("%c", s[i]);
20         }
21     }
22     printf("\n");
23 }

```

Program 3.10: uppercase0.c

[!htbp]

```

1  // Uppercases string using ctype library (and an unnecessary
   - condition)
2
3  #include <cs50.h>
4  #include <ctype.h>
5  #include <stdio.h>
6  #include <string.h>

```

```

7
8  int main(void)
9  {
10     string s = get_string("Before: ");
11     printf("After: ");
12     for (int i = 0, n = strlen(s); i < n; i++)
13     {
14         if (islower(s[i]))
15         {
16             printf("%c", toupper(s[i]));
17         }
18         else
19         {
20             printf("%c", s[i]);
21         }
22     }
23     printf("\n");
24 }

```

Program 3.11: uppercasel.c

3.6 Command Line Arguments

[!htbp]

```
1  // Printing a command-line argument
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  int main(int argc, string argv[])
7  {
8      if (argc == 2)
9      {
10         printf("hello, %s\n", argv[1]);
11     }
12     else
13     {
14         printf("hello, world\n");
15     }
16 }
```

Program 3.12: argv.c

[!htbp]

```
1  // Printing characters in an array of strings
2
3  #include <cs50.h>
4  #include <stdio.h>
5  #include <string.h>
6
7  int main(int argc, string argv[])
8  {
9      for (int i = 0; i < argc; i++)
10     {
11         for (int j = 0, n = strlen(argv[i]); j < n; j++)
12         {
13             printf("%c\n", argv[i][j]);
14         }
15         printf("\n");
16     }
17 }
```


Program 3.13: argv2.c

[!htbp]

```
1  // Returns explicit value from main
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  int main(int argc, string argv[])
7  {
8      if (argc != 2)
9      {
10         printf("missing command-line argument\n");
11         return 1;
12     }
13     printf("hello, %s\n", argv[1]);
14     return 0;
15 }
```

Program 3.14: exit.c

Chapter 4

Algorithms

4.1 Linear Search

```
1  for i from 0 to n-1
2      if ith element is 50
3          return true;
4  return false;
```

Program 4.1: Linear Search Pseudocode

4.2 Binary Search

```
1  if no items
2      return false;
3  if middle item is 50
4      return true;
5  else if 50 < middle item
6      search left half
7  else if 50 > middle item
8      search right half
```

Program 4.2: Binary Search Pseudocode

4.3 Efficiency

4.3.1 \mathcal{O} Notation:

Worst case scenario

$$\begin{aligned}n^2 &: \mathcal{O}(n^2) \\n \log_n n &: \mathcal{O}(n \log n) \\n &: \mathcal{O}(n) \text{ (LinearSearch)} \\n/2 &: \mathcal{O}(n) \\\log_2 n &: \mathcal{O}(\log n) \text{ (BinarySearch)} \\constant &: \mathcal{O}(1)\end{aligned}$$

4.3.2 Ω Notation:

Best case scenario

$$\begin{aligned}\Omega(n^2) \\ \Omega(n \log n) \\ \Omega(n) \\ \Omega(n) \\ \Omega(\log n) \\ \Omega(1)\end{aligned}$$

Q: Better to have a really good \mathcal{O} value or a really good Ω value?

A: \mathcal{O} , or even *average* case.

4.4 Examples

4.4.1 Linear Search

Numbers

```
1 // Implements linear search for numbers
2
3 #include <cs50.h>
4 #include <stdio.h>
5
6 int main(void)
7 {
8     // An array of numbers
9     int numbers[] = {4, 8, 15, 16, 23, 42};
10
11     // Search for 50
12     for (int i = 0; i < 6; i++)
13     {
14         if (numbers[i] == 50)
15         {
16             printf("Found\n");
17             return 0;
18         }
19     }
20     printf("Not found\n");
21     return 1;
22 }
```

Program 4.3: Linear Search on numbers

Names

```
1 // Implements linear search for names
2
3 #include <cs50.h>
4 #include <stdio.h>
5 #include <string.h>
6
7 int main(void)
8 {
```

```

9      // An array of names
10     string names[] = {"EMMA", "RODRIGO", "BRIAN", "DAVID"};
11
12     // Search for EMMA
13     for (int i = 0; i < 4; i++)
14     {
15         if (strcmp(names[i], "EMMA") == 0)
16         {
17             printf("Found\n");
18             return 0;
19         }
20     }
21     printf("Not found\n");
22     return 1;
23 }

```

Program 4.4: Linear Search on names

4.4.2 Bad Design

Correct/Working code but bad design!

```

1  // Implements a phone book without structs
2
3  #include <cs50.h>
4  #include <stdio.h>
5  #include <string.h>
6
7  int main(void)
8  {
9      string names[] = {"EMMA", "RODRIGO", "BRIAN", "DAVID"};
10     string numbers[] = {"617-555-0100", "617-555-0101",
11                          "617-555-0102", "617-555-0103"};
12
13     for (int i = 0; i < 4; i++)
14     {
15         if (!strcmp(names[i], "EMMA"))
16         {
17             printf("Found %s\n", numbers[i]);
18             return 0;
19         }
20     }
21 }

```

```

19     }
20     printf("Not found\n");
21     return 1;
22 }

```

Program 4.5: Linear Search in a phonebook

4.4.3 Good Design - typedef struct

Using `typedef struct` for better design!

```

1  // Implements a phone book with structs
2
3  #include <cs50.h>
4  #include <stdio.h>
5  #include <string.h>
6
7  typedef struct
8  {
9      string name;
10     string number;
11 }
12 person;
13
14 int main(void)
15 {
16     person people[4];
17
18     people[0].name = "EMMA";
19     people[0].number = "617-555-0100";
20
21     people[1].name = "RODRIGO";
22     people[1].number = "617-555-0101";
23
24     people[2].name = "BRIAN";
25     people[2].number = "617-555-0102";
26
27     people[3].name = "DAVID";
28     people[3].number = "617-555-0103";
29
30     // Search for EMMA

```

```

31     for (int i = 0; i < 4; i++)
32     {
33         if (strcmp(people[i].name, "EMMA") == 0)
34         {
35             printf("Found %s\n", people[i].number);
36             return 0;
37         }
38     }
39     printf("Not found\n");
40     return 1;
41 }

```

Program 4.6: Linear Search in phonebook with `typedef struct`

4.5 Bubble Sort

```

1  repeat n-1 times
2      for i = 0 to n-2
3          if ith and i+1th elements out of order
4              swap them

```

$\mathcal{O}(n^2)$

$\Omega(n^2)$

4.6 Selection Sort

```

1  for i from 0 to n-1
2      find smallest item between ith item and last item
3      swap smallest item and ith item

```

$\mathcal{O}(n^2)$

$\Omega(n^2)$

4.7 Better Bubble Sort

```
1 repeat until swap
2     for i = 0 to n-2
3         if ith and i+1th elements out of order
4             swap them
```

$\mathcal{O}(n^2)$

$\Omega(n)$

4.8 Recursion

```
1 Pick up phone book
2 Open to middle of phone book
3 Look at page
4 if Smith is on page
5     Call Mike
6 else if Smith is earlier in book
7     Open to middle of left half of book
8     Go back to line 3
9 else if Smith is later in book
10    Open to middle of right half of book
11    Go back to line 3
12 else
13    Quit
```

Program 4.7: Iteration Pseudocode

Can we do a better design?

```
1 Pick up phone book
2 Open to middle of phone book
3 Look at page
4 if Smith is on page
5     Call Mike
6 else if Smith is earlier in book
7     Search left half of book
8 else if Smith is later in book
9     Search right half of book
```



```

10 else
11     Quit

```

Program 4.8: Recursion Pseudocode

```

1  // Draws a pyramid using iteration
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  void draw(int h);
7
8  int main(void)
9  {
10     // Get height of pyramid
11     int height = get_int("Height: ");
12
13     // Draw pyramid
14     draw(height);
15 }
16
17 void draw(int h)
18 {
19     // Draw pyramid of height h
20     for (int i = 1; i <= h; i++)
21     {
22         for (int j = 1; j <= i; j++)
23         {
24             printf("#");
25         }
26         printf("\n");
27     }
28 }

```

Program 4.9: Iteration C code

```

1  // Draws a pyramid using recursion
2
3  #include <cs50.h>
4  #include <stdio.h>

```

```

5
6 void draw(int h);
7
8 int main(void)
9 {
10     // Get height of pyramid
11     int height = get_int("Height: ");
12
13     // Draw pyramid
14     draw(height);
15 }
16
17 void draw(int h)
18 {
19     // If nothing to draw
20     if (h == 0)
21     {
22         return;
23     }
24
25     // Draw pyramid of height h - 1
26     draw(h - 1);
27
28     // Draw one more row of width h
29     for (int i = 0; i < h; i++)
30     {
31         printf("#");
32     }
33     printf("\n");
34 }

```

Program 4.10: Recursion C code

4.9 Merge Sort

```
1  if only 1 item
2      return
3  else
4      sort left half of items
5      sort right half of items
6      merge sorted halves
```

Program 4.11: Merge Sort Pseudocode

$\mathcal{O}(n \log n)$

$\Omega(n \log n)$

4.9.1 Θ Notation

When $\mathcal{O} = \Omega$!

Chapter 5

Memory

Removing the training wheels `#include <cs50.h>` from now!

5.1 Hexadecimal

Digits: {1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F}

Ambiguity: Prefix the number with 0x

5.2 Addresses

```
1 // Prints an integer
2
3 #include <stdio.h>
4
5 int main(void)
6 {
7     int n = 50;
8     printf("%i\n", n);
9 }
```

Program 5.1: integer

```

1 // Prints an integer's address
2
3 #include <stdio.h>
4
5 int main(void)
6 {
7     int n = 50;
8     printf("%p\n", &n);
9 }

```

Program 5.2: address of an integer

```

1 // Prints an integer via its address
2
3 #include <stdio.h>
4
5 int main(void)
6 {
7     int n = 50;
8     printf("%i\n", *&n);
9 }

```

Program 5.3: address2.c

5.2.1 Operators

`&` = Get the address

`*` = Go to the address

5.3 Pointers

```
1 // Stores and prints an integer's address
2
3 #include <stdio.h>
4
5 int main(void)
6 {
7     int n = 50;
8     int *p = &n;
9     printf("%p\n", p);
10 }
```

Program 5.4: accessing an address

```
1 // Stores and prints an integer via its address
2
3 #include <stdio.h>
4
5 int main(void)
6 {
7     int n = 50;
8     int *p = &n;
9     printf("%i\n", *p);
10 }
```

Program 5.5: pointers

5.4 Strings

There are no strings. Strings are just pointers.

```
1 // Prints a string
2
3 #include <cs50.h>
4 #include <stdio.h>
5
6 int main(void)
7 {
8     string s = "EMMA";
9     printf("%s\n", s);
10 }
```

Program 5.6: strings

```
1 // Prints a string's address
2
3 #include <cs50.h>
4 #include <stdio.h>
5
6 int main(void)
7 {
8     string s = "EMMA";
9     printf("%p\n", s);
10 }
```

Program 5.7: strings are pointers

```
1 // Prints a string's address as well the addresses of its
  ↳ chars
2
3 #include <cs50.h>
4 #include <stdio.h>
5
6 int main(void)
7 {
8     string s = "EMMA";
9     printf("%p\n", s);
10    printf("%p\n", &s[0]);
```

```

11     printf("%p\n", &s[1]);
12     printf("%p\n", &s[2]);
13     printf("%p\n", &s[3]);
14     printf("%p\n", &s[4]);
15 }

```

Program 5.8: strings are `char []`
addresses are consecutive in arrays

```

1  // Prints a string's chars
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  int main(void)
7  {
8      string s = "EMMA";
9      printf("%c\n", s[0]);
10     printf("%c\n", s[1]);
11     printf("%c\n", s[2]);
12     printf("%c\n", s[3]);
13 }

```

Program 5.9: accessing characters in a string

```

1  // Stores and prints a string's address via pointer arithmetic
2
3  #include <stdio.h>
4
5  int main(void)
6  {
7      char *s = "EMMA";
8      printf("%c\n", *s);
9      printf("%c\n", *(s+1));
10     printf("%c\n", *(s+2));
11     printf("%c\n", *(s+3));
12 }

```

Program 5.10: accessing characters in a `char *`

5.5 String Comparision

```
1 // Compares two integers
2
3 #include <cs50.h>
4 #include <stdio.h>
5
6 int main(void)
7 {
8     // Get two integers
9     int i = get_int("i: ");
10    int j = get_int("j: ");
11
12    // Compare integers
13    if (i == j)
14    {
15        printf("Same\n");
16    }
17    else
18    {
19        printf("Different\n");
20    }
21 }
```

Program 5.11: comparing integers

```
1 // Compares two strings' addresses
2
3 #include <cs50.h>
4 #include <stdio.h>
5
6 int main(void)
7 {
8     // Get two strings
9     string s = get_string("s: ");
10    string t = get_string("t: ");
11
12    // Compare strings' addresses
13    if (s == t)
14    {
15        printf("Same\n");
```

```

16     }
17     else
18     {
19         printf("Different\n");
20     }
21 }

```

Program 5.12: attempting to compare strings directly

```

1  // Compares two strings using strcmp
2
3  #include <cs50.h>
4  #include <stdio.h>
5
6  int main(void)
7  {
8      // Get two strings
9      string s = get_string("s: ");
10     string t = get_string("t: ");
11
12     // Compare strings
13     if (strcmp(s, t) == 0)
14     {
15         printf("Same\n");
16     }
17     else
18     {
19         printf("Different\n");
20     }
21 }

```

Program 5.13: comparing strings properly

5.6 String Copy

```
1 // Capitalizes a string
2
3 #include <cs50.h>
4 #include <ctype.h>
5 #include <stdio.h>
6 #include <string.h>
7
8 int main(void)
9 {
10     // Get a string
11     string s = get_string("s: ");
12
13     // Copy string's address
14     string t = s;
15
16     // Capitalize first letter in string
17     if (strlen(t) > 0)
18     {
19         t[0] = toupper(t[0]);
20     }
21
22     // Print string twice
23     printf("s: %s\n", s);
24     printf("t: %s\n", t);
25 }
```

Program 5.14: attempting to copying strings directly

```
1 // Capitalizes a copy of a string
2
3 #include <cs50.h>
4 #include <ctype.h>
5 #include <stdio.h>
6 #include <stdlib.h>
7 #include <string.h>
8
9 int main(void)
10 {
11     // Get a string
```

```

12     char *s = get_string("s: ");
13
14     // Allocate memory for another string
15     char *t = malloc(strlen(s) + 1);
16
17     // Copy string into memory
18     for (int i = 0, n = strlen(s); i <= n; i++)
19     {
20         t[i] = s[i];
21     }
22
23     // Capitalize copy
24     t[0] = toupper(t[0]);
25
26     // Print strings
27     printf("s: %s\n", s);
28     printf("t: %s\n", t);
29 }

```

Program 5.15: copy strings properly
Just use strcpy(target, source) to copy strings.

5.7 Malloc and Free

malloc: Allocate Memory and return its address.

free: Free Memory (prevent leaking).

5.8 Buffer Overflow

```

1 // http://valgrind.org/docs/manual/quick-start.html
  ↳ #quick-start.prepare
2
3 #include <stdlib.h>
4
5 void f(void)
6 {
7     int *x = malloc(10 * sizeof(int));
8     x[10] = 0;

```

```

9   }
10
11  int main(void)
12  {
13      f();
14      return 0;
15  }

```

Program 5.16: buffer overflow

5.9 Swap

Pass by *value* vs pass by *reference*

```

1  // Fails to swap two integers
2
3  #include <stdio.h>
4
5  void swap(int a, int b);
6
7  int main(void)
8  {
9      int x = 1;
10     int y = 2;
11
12     printf("x is %i, y is %i\n", x, y);
13     swap(x, y);
14     printf("x is %i, y is %i\n", x, y);
15 }
16
17 void swap(int a, int b)
18 {
19     int tmp = a;
20     a = b;
21     b = tmp;
22 }

```

Program 5.17: naive attempt at swap

```

1  // Swaps two integers using pointers
2
3  #include <stdio.h>
4
5  void swap(int *a, int *b);
6
7  int main(void)
8  {
9      int x = 1;
10     int y = 2;
11
12     printf("x is %i, y is %i\n", x, y);
13     swap(&x, &y);
14     printf("x is %i, y is %i\n", x, y);
15 }
16
17 void swap(int *a, int *b)
18 {
19     int tmp = *a;
20     *a = *b;
21     *b = tmp;
22 }

```

Program 5.18: swap

5.10 scanf

```
1  // Gets an int from user using scanf
2
3  #include <stdio.h>
4
5  int main(void)
6  {
7      int x;
8      printf("x: ");
9      scanf("%i", &x);
10     printf("x: %i\n", x);
11 }
```

Program 5.19: scanning an integer

```
1  // Incorrectly gets a string from user using scanf
2
3  #include <stdio.h>
4
5  int main(void)
6  {
7      char *s;
8      printf("s: ");
9      scanf("%s", s);
10     printf("s: %s\n", s);
11 }
```

Program 5.20: scanning a string in uninitialized

```

1 // Dangerously gets a string from user using scanf
2
3 #include <stdio.h>
4
5 int main(void)
6 {
7     char s[5];
8     printf("s: ");
9     scanf("%s", s);
10    printf("s: %s\n", s);
11 }

```

Program 5.21: scanning a long string in small array

5.11 File I/O

```

1 // Saves names and numbers to a CSV file
2
3 #include <cs50.h>
4 #include <stdio.h>
5 #include <string.h>
6
7 int main(void)
8 {
9     // Open CSV file
10    FILE *file = fopen("phonebook.csv", "a");
11    if (!file)
12    {
13        return 1;
14    }
15
16    // Get name and number
17    string name = get_string("Name: ");
18    string number = get_string("Number: ");
19
20    // Print to file
21    fprintf(file, "%s,%s\n", name, number);
22

```



```

23     // Close file
24     fclose(file);
25 }

```

Program 5.22: files in c

```

1 Sparsh,6238-098-518

```

Program 5.23: phonebook.csv

```

1  // Detects if a file is a JPEG
2
3  #include <stdio.h>
4
5  int main(int argc, char *argv[])
6  {
7      // Check usage
8      if (argc != 2)
9      {
10         return 1;
11     }
12
13     // Open file
14     FILE *file = fopen(argv[1], "r");
15     if (!file)
16     {
17         return 1;
18     }
19
20     // Read first three bytes
21     unsigned char bytes[3];
22     fread(bytes, 3, 1, file);
23
24     // Check first three bytes
25     if (bytes[0] == 0xff && bytes[1] == 0xd8 && bytes[2] ==
        0xff)
26     {
27         printf("Maybe\n");
28     }
29     else

```

```
30     {
31         printf("No\n");
32     }
33
34     // Close file
35     fclose(file);
36 }
```

Program 5.24: check jpeg or not

Chapter 6

Data Structures

6.1 Arrays

- Fixed size
- Resizing \equiv Relocating
- This implies insert = $\mathcal{O}(n)$
- Search = $\mathcal{O}(\log n)$

```
1  // Implements a list of numbers with an array of fixed size
2
3  #include <stdio.h>
4
5  int main(void)
6  {
7      // List of size 3
8      int list[3];
9
10     // Initialize list with numbers
11     list[0] = 1;
12     list[1] = 2;
13     list[2] = 3;
14
15     // Print list
16     for (int i = 0; i < 3; i++)
17     {
18         printf("%i\n", list[i]);
```

```
19     }
20 }
```

Program 6.1: array with hardcoded size

```
1  // Implements a list of numbers with an array of dynamic size
2  //
3  #include <stdio.h>
4  #include <stdlib.h>
5
6  int main(void)
7  {
8      // List of size 3
9      int *list = malloc(3 * sizeof(int));
10     if (list == NULL)
11     {
12         return 1;
13     }
14
15     // Initialize list of size 3 with numbers
16     list[0] = 1;
17     list[1] = 2;
18     list[2] = 3;
19
20     // List of size 4
21     int *tmp = malloc(4 * sizeof(int));
22     if (tmp == NULL)
23     {
24         return 1;
25     }
26
27     // Copy list of size 3 into list of size 4
28     for (int i = 0; i < 3; i++)
29     {
30         tmp[i] = list[i];
31     }
32
33     // Add number to list of size 4
34     tmp[3] = 4;
35
36     // Free list of size 3
```

```

37     free(list);
38
39     // Remember list of size 4
40     list = tmp;
41
42     // Print list
43     for (int i = 0; i < 4; i++)
44     {
45         printf("%i\n", list[i]);
46     }
47
48     // Free list
49     free(list);
50 }

```

Program 6.2: array with dynamic size using malloc

```

1  // Implements a list of numbers with an array of dynamic size
   ↳ using realloc
2
3  #include <stdio.h>
4  #include <stdlib.h>
5
6  int main(void)
7  {
8      // List of size 3
9      int *list = malloc(3 * sizeof(int));
10     if (list == NULL)
11     {
12         return 1;
13     }
14
15     // Initialize list of size 3 with numbers
16     list[0] = 1;
17     list[1] = 2;
18     list[2] = 3;
19
20     // Resize list to be of size 4
21     int *tmp = realloc(list, 4 * sizeof(int));
22     if (tmp == NULL)
23     {

```

```

24         return 1;
25     }
26     list = tmp;
27
28     // Add number to list
29     list[3] = 4;
30
31     // Print list
32     for (int i = 0; i < 4; i++)
33     {
34         printf("%i\n", list[i]);
35     }
36
37     // Free list
38     free(list);
39 }

```

Program 6.3: array with dynamic size using realloc

6.2 Data Structures

Structures to store data. In c, it basically revolves around

- struct
- .
- *

6.3 Linked List

```

1 // Implements a list of numbers with linked list
2
3 #include <stdio.h>
4 #include <stdlib.h>
5
6 // Represents a node
7 typedef struct node
8 {
9     int number;

```

```

10     struct node *next;
11 }
12 node;
13
14 int main(void)
15 {
16     // List of size 0
17     node *list = NULL;
18
19     // Add number to list
20     node *n = malloc(sizeof(node));
21     if (n == NULL)
22     {
23         return 1;
24     }
25     n->number = 1;
26     n->next = NULL;
27     list = n;
28
29     // Add number to list
30     n = malloc(sizeof(node));
31     if (n == NULL)
32     {
33         return 1;
34     }
35     n->number = 2;
36     n->next = NULL;
37     list->next = n;
38
39     // Add number to list
40     n = malloc(sizeof(node));
41     if (n == NULL)
42     {
43         return 1;
44     }
45     n->number = 3;
46     n->next = NULL;
47     list->next->next = n;
48
49     // Print list
50     for (node *tmp = list; tmp != NULL; tmp = tmp->next)

```

```

51     {
52         printf("%i\n", tmp->number);
53     }
54
55     // Free list
56     while (list != NULL)
57     {
58         node *tmp = list->next;
59         free(list);
60         list = tmp;
61     }
62 }

```

Program 6.4: linked list

We have now lost random access. So:

- Search = $\mathcal{O}(n)$
- Insert = $\mathcal{O}(n)$

6.4 Tree

Think of as multi-dimensional linked lists.

6.4.1 Binary Search Tree

```

1  typedef struct node
2  {
3      int number;
4      struct node *left;
5      struct node *right;
6  }
7  node;

```

Program 6.5: node for a binary tree


```

1  bool search(node *tree, int n)
2  {
3      if (tree == NULL)
4      {
5          return false;
6      }
7      else if (n < tree->number)
8      {
9          return search(tree->left);
10     }
11     else if (n > tree->number)
12     {
13         return search(tree->right);
14     }
15     else
16     {
17         return true;
18     }
19 }

```

Program 6.6: search in a binary-search-tree

So, time complexity here:

- Search = $\mathcal{O}(\log n)$
- Insert = $\mathcal{O}(\log n)$ - need to balance the tree

6.5 Hash Table

Hoping for the best

- Search $\rightarrow \mathcal{O}(1)$, can actually be $\mathcal{O}(n)$ if we get really unlucky.

6.6 Trie

A tree who nodes are arrays! Time complexity:

- Search = $\mathcal{O}(1)$
- Insert = $\mathcal{O}(1)$

6.7 Queue

First In First Out

- enqueue
- dequeue

6.8 Stack

Last In First Out

- push
- pop

6.9 Dictionary

An abstraction on top of hash table. Has *keys* and *values*.

Chapter 7

Python

7.1 Introduction

```
1  # A program that says hello to the world
2
3  print("hello, world")
```

Program 7.1: Hello Python

To run: \$ python hello.py

```
1  # get_string and print, with concatenation
2
3  from cs50 import get_string
4
5  s = get_string("What's your name?\n")
6  print("hello, " + s)
```

Program 7.2: strings in python

```
1  # get_string and print, with multiple arguments
2
3  from cs50 import get_string
4
5  s = get_string("What's your name?\n")
6  print("hello,", s)
```

Program 7.3: print function in python

```

1  # get_string and print, with format strings
2
3  from cs50 import get_string
4
5  s = get_string("What's your name?\n")
6  print(f"hello, {s}")

```

Program 7.4: format strings

```

1  # get_int and print
2
3  from cs50 import get_int
4
5  age = get_int("What's your age?\n")
6  print(f"You are at least {age * 365} days old.")

```

Program 7.5: integers in python

```

1  # Conditions and relational operators
2
3  from cs50 import get_int
4
5  # Prompt user for x
6  x = get_int("x: ")
7
8  # Prompt user for y
9  y = get_int("y: ")
10
11 # Compare x and y
12 if x < y:
13     print("x is less than y")
14 elif x > y:
15     print("x is greater than y")
16 else:
17     print("x is equal to y")

```

Program 7.6: comparisons in python

```

1  # Logical operators
2
3  from cs50 import get_string
4
5  # Prompt user to agree
6  s = get_string("Do you agree?\n")
7
8  # Check whether agreed
9  if s == "Y" or s == "y":
10     print("Agreed.")
11 elif s == "N" or s == "n":
12     print("Not agreed.")

```

Program 7.7: logical operators in python

```

1  # Logical operators, using lists
2
3  from cs50 import get_string
4
5  # Prompt user to agree
6  s = get_string("Do you agree?\n")
7
8  # Check whether agreed
9  if s.lower() in ["y", "yes"]:
10     print("Agreed.")
11 elif s.lower() in ["n", "no"]:
12     print("Not agreed.")

```

Program 7.8: convert string to lowercase in python

```

1  # Loops
2
3  while True:
4     print("hello, world")

```

Program 7.9: while loop in python

```

1  # Better design
2
3  for i in range(3):
4      print("cough")

```

Program 7.10: for loop and `range` in python

```

1  # Abstraction
2
3
4  def main():
5      for i in range(3):
6          cough()
7
8
9  # Cough once
10 def cough():
11     print("cough")
12
13
14 main()

```

Program 7.11: functions in python

```

1  # Abstraction with parameterization
2
3
4  def main():
5      cough(3)
6
7
8  # Cough some number of times
9  def cough(n):
10     for i in range(n):
11         print("cough")
12
13
14 main()

```

Program 7.12: arguments to functions in python

```

1  # Abstraction and scope
2
3  from cs50 import get_int
4
5
6  def main():
7      i = get_positive_int()
8      print(i)
9
10
11 # Prompt user for positive integer
12 def get_positive_int():
13     while True:
14         n = get_int("Positive Integer: ")
15         if n > 0:
16             break
17     return n
18
19
20 main()

```

Program 7.13: scopes in python

```

1  # Prints a row of 4 question marks with a loop
2
3  for i in range(4):
4      print("?", end=" ")
5  print()

```

Program 7.14: named arguments in python

```

1  # Prints a row of 4 question marks without a loop
2
3  print("?" * 4)

```

Program 7.15: multiplying a string: pythonic

```

1  # Prints a 3-by-3 grid of bricks with loops
2
3  for i in range(3):
4      for j in range(3):
5          print("#", end="")
6      print()

```

Program 7.16: nested loops in python

```

1  # input and print, with format strings
2
3  s = input("What's your name?\n")
4  print(f"hello, {s}")

```

Program 7.17: input strings in python

```

1  # input, int, and print
2
3  age = int(input("What's your age?\n"))
4  print(f"You are at least {age * 365} days old.")

```

Program 7.18: input integers in python

```

1  # Integer non-overflow
2
3  from time import sleep
4
5  # Iteratively double i
6  i = 1
7  while True:
8      print(i)
9      sleep(1)
10     i *= 2

```

Program 7.19: overflow in python?

Remark. No limit of ints in python!


```

1  # Averages three numbers using a list with append
2
3  # Scores
4  scores = []
5  scores.append(72)
6  scores.append(73)
7  scores.append(33)
8
9  # Print average
10 print(f"Average: {sum(scores) / len(scores)}")

```

Program 7.20: lists in python

```

1  # Averages three numbers using a list
2
3  # Scores
4  scores = [72, 73, 33]
5
6  # Print average
7  print(f"Average: {sum(scores) / len(scores)}")

```

Program 7.21: directly using lists in python

```

1  # Prints string character by character, indexing into string
2
3  from cs50 import get_string
4
5  s = get_string("Input: ")
6  print("Output: ", end="")
7  for i in range(len(s)):
8      print(s[i], end="")
9  print()

```

Program 7.22: access characters of a string in python

```

1  # Prints string character by character
2
3  from cs50 import get_string
4
5  s = get_string("Input: ")
6  print("Output: ", end="")
7  for c in s:
8      print(c, end="")
9  print()

```

Program 7.23: accessing characters of a string directly in python

```

1  # Uppercases string
2
3  from cs50 import get_string
4
5  s = get_string("Before: ")
6  print("After: ", end="")
7  print(s.upper())

```

Program 7.24: changing to uppercase in python

```

1  # Printing command-line arguments, indexing into argv
2
3  from sys import argv
4
5  for i in range(len(argv)):
6      print(argv[i])

```

Program 7.25: command line arguments in python

```

1  # Printing command-line arguments
2
3  from sys import argv
4
5  for arg in argv:
6      print(arg)

```

Program 7.26: directly accessing command line arguments in python

```

1  # Exits with explicit value, importing argv and exit
2
3  from sys import argv, exit
4
5  if len(argv) != 2:
6      print("missing command-line argument")
7      exit(1)
8  print(f"hello, {argv[1]}")
9  exit(0)

```

Program 7.27: exiting on error in python

```

1  # Implements linear search for names
2
3  import sys
4
5  # A list of names
6  names = ["EMMA", "RODRIGO", "BRIAN", "DAVID"]
7
8  # Search for EMMA
9  if "EMMA" in names:
10     print("Found")
11     sys.exit(0)
12 print("Not found")
13 sys.exit(1)

```

Program 7.28: searching in a list in python

```

1  # Implements a phone book
2
3  import sys
4
5  people = {
6      "EMMA": "617-555-0100",
7      "RODRIGO": "617-555-0101",
8      "BRIAN": "617-555-0102",
9      "DAVID": "617-555-0103"
10 }
11
12 # Search for EMMA
13 if "EMMA" in people:
14     print(f"Found {people['EMMA']}")
15     sys.exit(0)
16 print("Not found")
17 sys.exit(1)

```

Program 7.29: dictionary in python

Remark. A dictionary (key/value pair) are also known as associative arrays.

```

1  # Compares two strings
2
3  from cs50 import get_string
4
5  # Get two strings
6  s = get_string("s: ")
7  t = get_string("t: ")
8
9  # Compare strings
10 if s == t:
11     print("Same")
12 else:
13     print("Different")

```

Program 7.30: string comparision in python

```

1  # Swaps two integers
2
3  x = 1
4  y = 2
5
6  print(f"x is {x}, y is {y}")
7  x, y = y, x
8  print(f"x is {x}, y is {y}")

```

Program 7.31: swapping values in python

```

1  # Saves names and numbers to a CSV file
2
3  import csv
4  from cs50 import get_string
5
6  # Open CSV file
7  file = open("phonebook.csv", "a")
8
9  # Get name and number
10 name = get_string("Name: ")
11 number = get_string("Number: ")
12
13 # Print to file
14 writer = csv.writer(file)
15 writer.writerow((name, number))
16
17 # Close file
18 file.close()

```

Program 7.32: files in python

```

1  # Saves names and numbers to a CSV file
2
3  import csv
4  from cs50 import get_string
5
6  # Get name and number

```

```

7  name = get_string("Name: ")
8  number = get_string("Number: ")
9
10 # Open CSV file
11 with open("phonebook.csv", "a") as file:
12
13     # Print to file
14     writer = csv.writer(file)
15     writer.writerow((name, number))

```

Program 7.33: `with` in python

7.2 Datatypes

- `bool`
- `float`
- `int`
- `str` \equiv `string`
- `range` \equiv sequence of numbers
- `list` \equiv sequence of mutable values
- `tuple` \equiv sequence of immutable values
- `dict` \equiv collection of key/value pairs
- `set` \equiv collection of unique values
- ...

7.3 Previous assignments from C to python

```
1  # Blurs an image
2
3  from PIL import Image, ImageFilter
4
5  # Blur image
6  before = Image.open("bridge.bmp")
7  after = before.filter(ImageFilter.BLUR)
8  after.save("out.bmp")
```

Program 7.34: blur.py: blur an image

```
1  # Words in dictionary
2  words = set()
3
4
5  def check(word):
6      """Return true if word is in dictionary else false"""
7      if word.lower() in words:
8          return True
9      else:
10         return False
11
12
13 def load(dictionary):
14     """Load dictionary into memory, returning true if
15     ↪ successful else false"""
16     file = open(dictionary, "r")
17     for line in file:
18         words.add(line.rstrip("\n"))
19     file.close()
20     return True
21
22 def size():
23     """Returns number of words in dictionary if loaded else 0
24     ↪ if not yet loaded"""
25     return len(words)
26
```

```

27 def unload():
28     """Unloads dictionary from memory, returning true if
        ↳ successful else false"""
29     return True

```

Program 7.35: dictionary.py: implement a dictionary

7.4 Regular Expressions

- . any character
- .* 0 or more characters
- .+ 1 or more characters
- ? optional

- ^ start of input
- \$ end of input

...

```

1  # Logical operators, using regular expressions
2
3  import re
4  from cs50 import get_string
5
6  # Prompt user to agree
7  s = get_string("Do you agree?\n")
8
9  # Check whether agreed
10 if re.search("^y(es)?$", s, re.IGNORECASE):
11     print("Agreed.")
12 elif re.search("^no?$", s, re.IGNORECASE):
13     print("Not agreed.")

```

Program 7.36: regex in python

7.5 Fancier stuff: Hardware usage

```
1  # Recognizes a greeting
2
3  # Get input
4  words = input("Say something!\n").lower()
5
6  # Respond to speech
7  if "hello" in words:
8      print("Hello to you too!")
9  elif "how are you" in words:
10     print("I am well, thanks!")
11 elif "goodbye" in words:
12     print("Goodbye to you too!")
13 else:
14     print("Huh?")
```

Program 7.37: extremely simple AI

```
1  # Recognizes a voice
2  # https://pypi.org/project/SpeechRecognition/
3
4  import speech_recognition
5
6  # Obtain audio from the microphone
7  recognizer = speech_recognition.Recognizer()
8  with speech_recognition.Microphone() as source:
9      print("Say something!")
10     audio = recognizer.listen(source)
11
12 # Recognize speech using Google Speech Recognition
13 print("Google Speech Recognition thinks you said:")
14 print(recognizer.recognize_google(audio))
```

Program 7.38: speech recognition in python

```

1  # Responds to a greeting
2  # https://pypi.org/project/SpeechRecognition/
3
4  import speech_recognition
5
6  # Obtain audio from the microphone
7  recognizer = speech_recognition.Recognizer()
8  with speech_recognition.Microphone() as source:
9      print("Say something!")
10     audio = recognizer.listen(source)
11
12 # Recognize speech using Google Speech Recognition
13 words = recognizer.recognize_google(audio)
14
15 # Respond to speech
16 if "hello" in words:
17     print("Hello to you too!")
18 elif "how are you" in words:
19     print("I am well, thanks!")
20 elif "goodbye" in words:
21     print("Goodbye to you too!")
22 else:
23     print("Huh?")

```

Program 7.39: reply with speech recognition in python

```

1  # Responds to a name
2  # https://pypi.org/project/SpeechRecognition/
3
4  import re
5  import speech_recognition
6
7  # Obtain audio from the microphone
8  recognizer = speech_recognition.Recognizer()
9  with speech_recognition.Microphone() as source:
10     print("Say something!")
11     audio = recognizer.listen(source)
12
13 # Recognize speech using Google Speech Recognition

```

```
14 words = recognizer.recognize_google(audio)
15
16 # Respond to speech
17 matches = re.search("my name is (.*)", words)
18 if matches:
19     print(f"Hey, {matches[1]}.")
20 else:
21     print("Hey, you.")
```

Program 7.40: interactive speech recognition in python

We can:

- Detect all the faces in a photo.
- Recognize a face.
- Create a QR code.

Chapter 8

Database

8.1 csv files

```
1 import csv
2
3 # Open CSV file
4 with open("CS50 2019 - Lecture 7 - Favorite TV Shows
  ↳ (Responses) - Form Responses 1.csv", "r") as file:
5
6     # Create DictReader
7     reader = csv.DictReader(file)
8
9     # Iterate over CSV file, printing each title
10    for row in reader:
11        print(row["title"])
```

Program 8.1: Read a csv file in python

```

1  import csv
2
3  # For counting favorites
4  counts = {}
5
6  # Open CSV file
7  with open("CS50 2019 - Lecture 7 - Favorite TV Shows
    - (Responses) - Form Responses 1.csv", "r") as file:
8
9      # Create DictReader
10     reader = csv.DictReader(file)
11
12     # Iterate over CSV file
13     for row in reader:
14
15         # Force title to lowercase
16         title = row["title"].lower()
17
18         # Add title to counts
19         if title in counts:
20             counts[title] += 1
21         else:
22             counts[title] = 1
23
24     # Print counts
25     for title, count in counts.items():
26         print(title, count, sep=" | ")

```

Program 8.2: Use a dictionary to count in python

```

1  import csv
2
3  # For counting favorites
4  counts = {}
5
6  # Open CSV file
7  with open("CS50 2019 - Lecture 7 - Favorite TV Shows
    - (Responses) - Form Responses 1.csv", "r") as file:
8

```

```

9      # Create DictReader
10     reader = csv.DictReader(file)
11
12     # Iterate over CSV file
13     for row in reader:
14
15         # Force title to lowercase
16         title = row["title"].lower()
17
18         # Add title to counts
19         if title in counts:
20             counts[title] += 1
21         else:
22             counts[title] = 1
23
24     # Print counts, sorted by title
25     for title, count in sorted(counts.items()):
26         print(title, count, sep=" | ")

```

Program 8.3: Print sorted dictionary by 'keys' in python

```

1  import csv
2
3  # For counting favorites
4  counts = {}
5
6  # Open CSV file
7  with open("CS50 2019 - Lecture 7 - Favorite TV Shows
   ↳ (Responses) - Form Responses 1.csv", "r") as file:
8
9      # Create DictReader
10     reader = csv.DictReader(file)
11
12     # Iterate over CSV file
13     for row in reader:
14
15         # Force title to lowercase
16         title = row["title"].lower()
17
18         # Add title to counts
19         if title in counts:

```

```

20         counts[title] += 1
21     else:
22         counts[title] = 1
23
24     # Function for comparing items by value
25     def f(item):
26         return item[1]
27
28     # Print counts, sorted by key
29     for title, count in sorted(counts.items(), key=f,
30                               ↪ reverse=True):
31         print(title, count, sep=" | ")

```

Program 8.4: Print sorted dictionary by 'values' in python

```

1  import csv
2
3  # For counting favorites
4  counts = {}
5
6  # Open CSV file
7  with open("CS50 2019 - Lecture 7 - Favorite TV Shows
8  ↪ (Responses) - Form Responses 1.csv", "r") as file:
9
10     # Create DictReader
11     reader = csv.DictReader(file)
12
13     # Iterate over CSV file
14     for row in reader:
15
16         # Force title to lowercase
17         title = row["title"].lower()
18
19         # Add title to counts
20         if title in counts:
21             counts[title] += 1
22         else:
23             counts[title] = 1
24
25     # Print counts, sorted by key

```

```

25 for title, count in sorted(counts.items(), key=lambda item:
    ↪ item[1], reverse=True):
26     print(title, count, sep=" | ")

```

Program 8.5: lambda function in python

8.2 SQL

8.2.1 Example

Open as sqlite3 <dbname>:

```

1 .mode csv
2 .import <filename> <tablename>

```

Program 8.6: load a csv to a db in sqlite3

Now we can ask the same kind of questions:

```

1 SELECT title FROM favorites;
2 SELECT title FROM favorites ORDER BY title;
3 SELECT title, COUNT(title) FROM favorites GROUP BY title;
4 SELECT title, COUNT(title) FROM favorites GROUP BY title LIMIT
    ↪ 10;
5 SELECT title, COUNT(title) AS n FROM favorites GROUP BY title
    ↪ LIMIT 10;
6 SELECT title, COUNT(title) AS n FROM favorites GROUP BY title
    ↪ ORDER BY n DESC LIMIT 10;

```

Program 8.7: SQL queries in sqlite3

8.2.2 Relational Database

With any form of data, there are four fundamental operations:

C: Create

R: Read

U: Update

D: Delete

Structured Query Language is just another programming language mainly used for databases, has keywords attached to these:

1. INSERT
2. SELECT
3. UPDATE
4. DELETE
- ...

8.2.3 Syntax

Datatypes:

1. BLOB - Binary Large Object
2. INTEGER
 - (a) smallint
 - (b) integer
 - (c) bigint
3. NUMERIC
 - (a) boolean
 - (b) date
 - (c) datetime
 - (d) numeric(scale,precision)
 - (e) time
 - (f) timestamp
4. REAL
 - (a) real
 - (b) double precision
5. TEXT
 - (a) char(n)
 - (b) varchar(n)
 - (c) text

Functions

1. AVG
2. COUNT
3. DISTINCT
4. MAX
5. MIN
- ...

Features

1. WHERE
2. LIKE
3. LIMIT
4. GROUP BY
5. ORDER BY
6. JOIN
- ...

```
1 CREATE TABLE table (column type, ...);
2 INSERT INTO table (column, ...) VALUES (value, ...);
3 SELECT columns FROM table;
4 SELECT title FROM favorites WHERE title LIKE "%office%";
5 SELECT COUNT(title) FROM favorites WHERE title LIKE "%office%";
6 SELECT columns FROM table WHERE condition;
7 UPDATE table SET column=value WHERE condition;
8 DELETE FROM table WHERE condition;
```

Program 8.8: SQL Syntax

8.2.4 Huge Database

Design decisions really gonna matter. Download "title.basic.tsv.gz" for example.

Fields

1. tcost : tt4786824
2. tyleType : tvSeries
3. primaryTitle : The Crown
4. startYear : 2016
5. genres : Drama, History

```
1  import csv
2
3  # Open TSV file
4  # https://datasets.imdbws.com/title.basics.tsv.gz
5  with open("title.basics.tsv", "r") as titles:
6
7      # Create DictReader
8      reader = csv.DictReader(titles, delimiter="\t")
9
10     # Open CSV file
11     with open("shows2.csv", "w") as shows:
12
13         # Create writer
14         writer = csv.writer(shows)
15
16         # Write header
17         writer.writerow(["tconst", "primaryTitle", "startYear",
18             ↪ "genres"])
19
20         # Iterate over TSV file
21         for row in reader:
22
23             # If non-adult TV show
24             if row["titleType"] == "tvSeries" and
25                 ↪ row["isAdult"] == "0":
```

```

24
25         # If year not missing
26         if row["startYear"] != "\\N":
27
28             # Remove \N from genres
29             genres = row["genres"] if row["genres"] !=
                ↳ "\\N" else None
30
31             # If since 1970
32             if int(row["startYear"]) >= 1970:
33
34                 # Write row
35                 writer.writerow([row["tconst"],
                    ↳ row["primaryTitle"],
                    ↳ row["startYear"], genres])

```

Program 8.9: filtering the database in python

```

1  import csv
2
3  # Prompt user for title
4  title = input("Title: ")
5
6  # Open CSV file
7  with open("shows2.csv", "r") as input:
8
9      # Create DictReader
10     reader = csv.DictReader(input)
11
12     # Iterate over CSV file
13     for row in reader:
14
15         # Search for title
16         if title.lower() == row["primaryTitle"].lower():
17             print(row["primaryTitle"], row["startYear"],
                ↳ row["genres"], sep=" | ")

```

Program 8.10: searching the database in python

```

1  import cs50
2  import csv
3
4  # Create database
5  open("shows3.db", "w").close()
6  db = cs50.SQL("sqlite:///shows3.db")
7
8  # Create table
9  db.execute("CREATE TABLE shows (tconst TEXT, primaryTitle TEXT,
10             \t startYear NUMERIC, genres TEXT)")
11
12 # Open TSV file
13 # https://datasets.imdbws.com/title.basics.tsv.gz
14 with open("title.basics.tsv", "r") as titles:
15
16     # Create DictReader
17     reader = csv.DictReader(titles, delimiter="\t")
18
19     # Iterate over TSV file
20     for row in reader:
21
22         # If non-adult TV show
23         if row["titleType"] == "tvSeries" and row["isAdult"] ==
24             \t "0":
25
26             # If year not missing
27             if row["startYear"] != "\\N":
28
29                 # If since 1970
30                 startYear = int(row["startYear"])
31                 if startYear >= 1970:
32
33                     # Remove \N from genres
34                     genres = row["genres"] if row["genres"] !=
35                         \t "\\N" else None
36
37                     # Insert show

```

```

35         db.execute("INSERT INTO shows (tconst,
        ↪ primaryTitle, startYear, genres)
        ↪ VALUES(?, ?, ?, ?)",
36                 row["tconst"],
        ↪ row["primaryTitle"],
        ↪ startYear, genres)

```

Program 8.11: using SQL in python

```

1  import cs50
2  import csv
3
4  # Create database
5  open("shows4.db", "w").close()
6  db = cs50.SQL("sqlite:///shows4.db")
7
8  # Create tables
9  db.execute("CREATE TABLE shows (id INT, title TEXT, year
    ↪ NUMERIC, PRIMARY KEY(id))")
10 db.execute("CREATE TABLE genres (show_id INT, genre TEXT,
    ↪ FOREIGN KEY(show_id) REFERENCES shows(id))")
11
12 # Open TSV file
13 # https://datasets.imdbws.com/title.basics.tsv.gz
14 with open("title.basics.tsv", "r") as titles:
15
16     # Create DictReader
17     reader = csv.DictReader(titles, delimiter="\t")
18
19     # Iterate over TSV file
20     for row in reader:
21
22         # If non-adult TV show
23         if row["titleType"] == "tvSeries" and row["isAdult"] ==
            ↪ "0":
24
25             # If year not missing
26             if row["startYear"] != "\\N":
27
28                 # If since 1970
29                 startYear = int(row["startYear"])

```

```

30         if startYear >= 1970:
31
32             # Trim prefix from tconst
33             id = int(row["tconst"][2:])
34
35             # Insert show
36             db.execute("INSERT INTO shows (id, title,
37                 ↳ year) VALUES(?, ?, ?)", id,
38                 ↳ row["primaryTitle"], startYear)
39
40             # Insert genres
41             if row["genres"] != "\\N":
42                 for genre in row["genres"].split(","):
43                     db.execute("INSERT INTO genres
44                         ↳ (show_id, genre) VALUES(?, ?)",
45                         ↳ id, genre)

```

Program 8.12: import to multiple tables in SQL using python

```

1  SELECT * FROM shows WHERE id IN (SELECT show_id FROM genres
   ↳ WHERE genre = "Comedy") AND year = 2019;

```

Program 8.13: query with multiple tables in SQL

```

1  CREATE INDEX person_index ON stars (person_id);

```

Program 8.14: indexing in sql

8.3 Problems

8.3.1 Race Conditions

Solution? *Transactions*

8.3.2 SQL Injection Attacks

Solution? *Sanitize your inputs*

Chapter 9

Summary

9.1 How far we have come!

```
1 from time import sleep
2
3 for i in range(0000, 10000):
4     print(f"Checking {i:04}...")
5     sleep(.1)
```

Program 9.1: brute-forcing 4-digit pins in python

```
1 from time import sleep
2
3 with open("large", "r") as file:
4     for word in file.readlines():
5         print(f"Checking {word.rstrip()}...")
6         sleep(.1)
```

Program 9.2: brute-forcing dictionary words in python

9.2 Ethics

With great power, comes great responsibility!

9.3 Git

Version Control!

9.4 Security

Nothing is fundamentally secure! Only to a certain degree.

9.4.1 Passwords

One level of security. Choose better passwords please!

9.4.2 Brute-Force Attack

9.4.3 Two-Factor Authentication

9.4.4 Password Managers

9.4.5 Encryption

End-to-End Encryption

9.5 Tracks

9.5.1 Web Programming

With HTML, CSS, and JavaScript (Plus Python and SQL)

9.5.2 Mobile App Development

for iOS with Swift

for Android with Java

9.5.3 Game Development

With Lua

Part II

Web

Chapter 10

Introduction

1. HTML
2. CSS
3. JavaScript
4. Flask
5. Python
6. SQL

10.1 Protocols

Protocols, set of rules to communicate. Standard *TCP/IP*.

10.1.1 IP addresses

IPv4

$\#. \#. \#. \# \equiv (0-255).(0-255).(0-255).(0-255)$, 8-bit each (32 bits total). A total of about 4 billion addresses.

IPv6

128-bit addresses.

10.1.2 Port Numbers

FTP : 21
(e-mail) SMTP : 25
HTTP : 80

Example: 1.2.3.4:80

10.1.3 URL: Domain Name System

Example: <http://www.example.com>

DNS

Mapping between URLs with their corresponding IP Address

10.1.4 HTTP(S)

HyperText Transfer Protocol (Secure)

10.1.5 Status Codes

Status Code	Description
200	OK
301	Moved Permanently
403	Forbidden
404	Not Found
500	Internal Server Error

Chapter 11

HTML

```
1  <!DOCTYPE html>
2
3  <!-- Demonstrates HTML -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Hello!
9          </title>
10     </head>
11     <body>
12         Hello, world!
13     </body>
14 </html>
```

Program 11.1: hello html

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates images and attributes -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Image
9          </title>
10     </head>
11     <body>
12         
13     </body>
14 </html>

```

Program 11.2: image in html

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates links -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Link
9          </title>
10     </head>
11     <body>
12         Visit <a href="https://harvard.edu">Harvard</a>.
13     </body>
14 </html>

```

Program 11.3: link in html

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates paragraphs -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Paragraphs
9          </title>
10     </head>
11     <body>
12         <p>This is paragraph one.</p>
13
14         <p>This is paragraph two.</p>
15
16         <p>This is paragraph three.</p>
17     </body>
18 </html>

```

Program 11.4: paragraphs in html

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates headings -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Headings
9          </title>
10     </head>
11     <body>
12         <h1>Title of my page</h1>
13
14         <h2>First subsection</h2>
15
16         <p>This is paragraph one.</p>
17
18         <p>This is paragraph two.</p>

```

```

19
20     <h2>Second subsection</h2>
21
22     <p>This is paragraph three.</p>
23 </body>
24 </html>

```

Program 11.5: headings in html

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates tables -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Table
9          </title>
10     </head>
11     <body>
12         <table>
13             <tr>
14                 <td>cell 1</td>
15                 <td>cell 2</td>
16                 <td>cell 3</td>
17             </tr>
18             <tr>
19                 <td>cell 4</td>
20                 <td>cell 5</td>
21                 <td>cell 6</td>
22             </tr>
23         </table>
24     </body>
25 </html>

```

Program 11.6: table in html


```
1  <!DOCTYPE html>
2
3  <!-- Demonstrates HTML forms -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Form
9          </title>
10     </head>
11     <body>
12         <form action="https://www.google.com/search"
13             ↪ method="get">
14             <input name="q" type="text">
15             <input type="submit" value="Submit Form">
16         </form>
17     </body>
18 </html>
```

Program 11.7: form in html

Chapter 12

CSS

Cascading Style Sheets: To *style* webpages.

```
1  <!DOCTYPE html>
2
3  <!-- Demonstrates inline CSS -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Hello!
9          </title>
10     </head>
11     <body>
12         <h1 style="color: blue;">Hello, world!</h1>
13
14         <p>This is my webpage.</p>
15     </body>
16 </html>
```

Program 12.1: inline styling in html

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates inline CSS -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Hello!
9          </title>
10     </head>
11     <body style="color: red">
12         <h1>Hello, world!</h1>
13
14         <p style="text-align: center; font-size: large;">This
15             is my webpage.</p>
16     </body>
17 </html>

```

Program 12.2: multiple styles within an html element

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates CSS classes -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Hello!
9          </title>
10         <style>
11             .title
12             {
13                 text-align: center;
14                 color: blue;
15             }
16         </style>
17     </head>
18     <body>
19         <h1 class="title">Hello, world!</h1>

```

```

20
21     <h2 class="title">Subsection 1</h2>
22
23     <p>This is some text.</p>
24
25     <h2 class="title">Subsection 2</h2>
26
27     <p>This is some text.</p>
28 </body>
29 </html>

```

Program 12.3: css classes in html

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates external style sheet -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Hello!
9          </title>
10         <link rel="stylesheet" href="css3.css">
11     </head>
12     <body>
13         <h1 class="title green">Hello, world!</h1>
14
15         <h2 class="title">Subsection 1</h2>
16
17         <p class="green">This is some text.</p>
18
19         <h2 class="title">Subsection 2</h2>
20
21         <p class="green">This is some text.</p>
22     </body>
23 </html>

```

Program 12.4: multiple css classes in an html element

```

1  .title
2  {
3      text-align: center;
4      font-family: sans-serif;
5  }
6
7  .green
8  {
9      color: green;
10 }

```

Program 12.5: separate css file

Remark. To link your css file in your html, do so in your *head* section via `<link rel="stylesheet" href="styles.css">`.

Remark. We can also link multiple different css files.

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates CSS styling of a table -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Table
9          </title>
10         <style>
11             table
12             {
13                 border: 1px solid black;
14                 border-collapse: collapse;
15             }
16
17             td
18             {
19                 border: 1px solid black;
20                 padding: 5px;
21             }
22

```

```

23         th
24     {
25         background-color: blue;
26     }
27 </style>
28 </head>
29 <body>
30     <table>
31         <tr>
32             <th>cell 1</th>
33             <th>cell 2</th>
34             <th>cell 3</th>
35         </tr>
36         <tr>
37             <td>cell 4</td>
38             <td>cell 5</td>
39             <td>cell 6</td>
40         </tr>
41         <tr>
42             <td>cell 7</td>
43             <td>cell 8</td>
44             <td>cell 9</td>
45         </tr>
46     </table>
47 </body>
48 </html>

```

Program 12.6: styled table in html

Libraries: Many predefined css libraries available to use.

Remark. *Bootstrap* is a popular css library.

```
1  <!DOCTYPE html>
2
3  <!-- Demonstrates Bootstrap -->
4
5  <html lang="en">
6
7  <head>
8      <title>
9          Bootstrap
10     </title>
11 </head>
12 <!-- concatenate the strings before using in real world -->
13 <link rel="stylesheet"
14     ↪ href="https://stackpath.bootstrapcdn.com" +
15     ↪ "/bootstrap/4.3.1/css/bootstrap.min.css"
16     ↪ integrity="sha384-ggOyR0iXCbMQv3Xipma34MD+dH" +
17     ↪ "/1fQ784/j6cY/iJTQUOhcWr7x9JvoRxT2MZw1T"
18     ↪ crossorigin="anonymous">
19
20 <body>
21     <h1>Hello, world!</h1>
22     <div class="alert alert-primary" role="alert">
23         This is my alert!
24     </div>
25 </body>
26 </html>
```

Program 12.7: using bootstrap css library

Chapter 13

JavaScript

A programming language to make webpages more interactive!

13.1 Syntax

A lot like C.

```
1  let counter = 0;
2  counter = counter + 1;
3  counter += 1;
4  counter++;
5  if (x < y)
6  {
7
8  }
9  else if (x > y)
10 {
11
12 }
13 else
14 {
15
16 }
17 while (true)
18 {
19
20 }
21 for (let i = 0; i < 50; i++)
22 {
```



```

23
24 }
25 function cough(n)
26 {
27
28 }

```

Program 13.1: JavaScript syntax

13.2 Document Object Model

Webpage as a DOM object!

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates alert that accesses the DOM -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Alert
9          </title>
10         <script>
11             function greet()
12             {
13                 let name =
14                     - document.querySelector('#name').value;
15                 if (name === '')
16                 {
17                     name = 'world';
18                 }
19                 alert('Hello, ' + name + '!');
20             }
21         </script>
22     </head>
23     <body>
24         <form onsubmit="greet(); return false;">
25             <input type="text" id="name">
26             <input type="submit">
27         </form>

```

```

27     </body>
28 </html>

```

Program 13.2: Alert using JavaScript

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates DOM manipulation -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Hello
9          </title>
10         <script>
11             function greet()
12             {
13                 let name =
14                     - document.querySelector('#name').value;
15                 if (name === '')
16                 {
17                     name = 'world';
18                 }
19                 document.querySelector('#result').innerHTML =
20                     - 'Hello, ' + name + '!';
21             }
22         </script>
23     </head>
24     <body>
25         <form onsubmit="greet(); return false;">
26             <input type="text" id="name">
27             <input type="submit">
28         </form>
29         <div id="result">
30             Hello!
31         </div>
32     </body>
33 </html>

```

Program 13.3: Updating webpage using JavaScript

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates DOM manipulation -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Counter
9          </title>
10         <script>
11             let counter = 0;
12
13             function increment()
14             {
15                 counter++;
16                 document.querySelector('#result').innerHTML =
17                     counter;
18             }
19         </script>
20     </head>
21     <body>
22         <form onsubmit="increment(); return false;">
23             <input type="submit">
24         </form>
25         <div id="result">
26             0
27         </div>
28     </body>
29 </html>

```

Program 13.4: Variables in a webpage using JavaScript

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates onclick event handler -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Background
9          </title>
10     </head>
11     <body>
12         <button id="red">R</button>
13         <button id="green">G</button>
14         <button id="blue">B</button>
15         <script>
16             let body = document.querySelector('body');
17             document.querySelector('#red').onclick = function()
18                 ↪ {
19                 body.style.backgroundColor = 'red';
20             }
21             document.querySelector('#green').onclick =
22                 ↪ function() {
23                 body.style.backgroundColor = 'green';
24             }
25             document.querySelector('#blue').onclick =
26                 ↪ function() {
27                 body.style.backgroundColor = 'blue';
28             }
29         </script>
30     </body>
31 </html>

```

Program 13.5: Changing background using JavaScript

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates onchange event handler -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Size
9          </title>
10     </head>
11     <body>
12         <p>This is some text.</p>
13         <select>
14             <option value="large">Large Text</option>
15             <option value="initial" selected>Medium
16                 Text</option>
17             <option value="small">Small Text</option>
18         </select>
19         <script>
20             document.querySelector('select').onchange =
21                 function() {
22                     document.querySelector('p').style.fontSize =
23                         this.value;
24                 }
25         </script>
26     </body>
27 </html>

```

Program 13.6: Updating font size using JavaScript

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates intervals -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Blink
9          </title>
10     </head>
11     <script>
12         function blink()
13         {
14             let body = document.querySelector('body');
15             if (body.style.visibility === 'hidden')
16             {
17                 body.style.visibility = 'visible';
18             }
19             else
20             {
21                 body.style.visibility = 'hidden';
22             }
23         }
24     }
25
26     // Blink every 500ms
27     window.setInterval(blink, 500);
28 </script>
29 <body>
30     Hello, world!
31 </body>
32 </html>

```

Program 13.7: Blinking a content using JavaScript

```

1  function blink()
2  {
3      let body = document.querySelector('body');
4      if (body.style.visibility === 'hidden')
5      {
6          body.style.visibility = 'visible';
7      }
8      else
9      {
10         body.style.visibility = 'hidden';
11     }
12 }
13
14
15 // Blink every 500ms
16 window.setInterval(blink, 500);

```

Program 13.8: JavaScript code in a separate file

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates external JS file -->
4
5  <html lang="en">
6      <head>
7          <title>
8              Blink
9          </title>
10     </head>
11     <script src="blink1.js"></script>
12     <body>
13         Hello, world!
14     </body>
15 </html>

```

Program 13.9: HTML using external JavaScript file

```

1  <!DOCTYPE html>
2
3  <!-- Demonstrates geolocation -->
4
5  <html lang="en">
6
7  <head>
8      <title>
9          Geolocation
10     </title>
11     <script>
12         navigator.geolocation.getCurrentPosition(function
13             ↪ (position) {
14             document.write(position.coords.latitude + ', ' +
15             ↪ position.coords.longitude);
16         });
17     </script>
18 </head>
19
20 <body>
21 </body>
22 </html>

```

Program 13.10: Getting location of the user via JavaScript

Chapter 14

Flask

Python based framework to write our own web-server.

14.1 Hello World

Remark. It is conventional to name the file 'application.py'.

```
1  from flask import Flask
2
3  app = Flask(__name__)
4
5  @app.route("/")
6  def index():
7      return "Hello, world!"
8
9  @app.route("/goodbye")
10 def bye():
11     return "Goodbye!"
```

Program 14.1: Hello World in Flask

In Program 14.1 variable `app` represents the web application we will run, and `__name__` represents the current file/program. For every route (path), we define a function to return the content we want while visiting that route.

To run your web application, when you are in the directory, you can type `flash run` to run the web application.

Remark. You might want to set the following environment variables first:

1. `export FLASK_APP=application.py`

```
2. export FLASK_ENV=development
```

Remark. You can return any HTML that you want!

14.2 Templates

Use templates to use external HTML files in Flask!

```
1 from flask import Flask, render_template
2
3 app = Flask(__name__)
4
5 @app.route("/")
6 def index():
7     return render_template("index.html")
8
9 @app.route("/goodbye")
10 def bye():
11     return "Goodbye!"
```

Program 14.2: Templates in Flask

14.3 Variables

14.3.1 String

```
1 from flask import Flask, render_template
2
3 app = Flask(__name__)
4
5 @app.route("/")
6 def index():
7     return render_template("index.html", name="Emma")
8
9 @app.route("/goodbye")
10 def bye():
11     return "Goodbye!"
```

Program 14.3: Variables in Flask

```

1  <!DOCTYPE html>
2
3  <html lang="en">
4      <head>
5          <title>Hello</title>
6      </head>
7      <body>
8          Hello, {{ name }}!
9      </body>
10 </html>

```

Program 14.4: Jinja syntax for (flask) variables in HTML

14.3.2 Random Numbers

```

1  import random
2
3  from flask import Flask, render_template
4
5  app = Flask(__name__)
6
7  @app.route("/")
8  def index():
9      number = random.randint(1, 10)
10     return render_template("index.html", number=number)
11
12 @app.route("/goodbye")
13 def bye():
14     return "Goodbye!"

```

Program 14.5: Passing Random Numbers from Flask

```

1  <!DOCTYPE html>
2
3  <html lang="en">
4      <head>
5          <title>Random</title>
6      </head>
7      <body>
8          Your random number is {{ number }}.
9      </body>
10 </html>

```

Program 14.6: Displaying random numbers in HTML

14.4 Conditions

14.4.1 Coin Flip

```

1  import random
2
3  from flask import Flask, render_template
4
5  app = Flask(__name__)
6
7  @app.route("/")
8  def index():
9      number = random.randint(0, 1)
10     return render_template("index.html", number=number)
11
12 @app.route("/goodbye")
13 def bye():
14     return "Goodbye!"

```

Program 14.7: Coin Flipping in flask

```

1  <!DOCTYPE html>
2
3  <html lang="en">
4      <head>
5          <title>Coin Flip</title>
6      </head>
7      <body>
8          {% if number == 1 %}
9              Your coin flip is HEADS.
10         {% else %}
11             Your coin flip is TAILS.
12         {% endif %}
13     </body>
14 </html>

```

14.5 Interactive Webpage

14.5.1 Forms

```

1  from flask import Flask, render_template, request
2
3  app = Flask(__name__)
4
5  @app.route("/")
6  def index():
7      return render_template("index.html")
8
9  @app.route("/hello")
10 def hello():
11     name = request.args.get("name")
12     if not name:
13         return render_template("failure.html")
14     return render_template("hello.html", name=name)

```

Program 14.8: Requesting arguments in flask

```

1  <!DOCTYPE html>
2
3  <html lang="en">
4      <head>
5          <title>Hello</title>
6      </head>
7      <body>
8          <form action="/hello">
9              <input name="name" type="text">
10                 <input type="submit">
11             </form>
12     </body>
13 </html>

```

Program 14.9: Requesting name in HTML

```

1  <!DOCTYPE html>
2
3  <html lang="en">
4      <head>
5          <title>Hello</title>
6      </head>
7      <body>
8          Hello, {{ name }}!
9      </body>
10 </html>

```

Program 14.10: Hello (name) in HTML

```
1  <!DOCTYPE html>
2
3  <html lang="en">
4      <head>
5          <title>Hello</title>
6          <style>
7              body
8              {
9                  color: red;
10             }
11         </style>
12     </head>
13     <body>
14         You must provide a name!
15     </body>
16 </html>
```

Program 14.11: Failure page in HTML

14.6 Layouts

Use layouts to include common HTML code.

```
1  <!DOCTYPE html>
2
3  <html lang="en">
4      <head>
5          <title>Hello</title>
6          <style>
7              {% block style %}
8              {% endblock %}
9          </style>
10     </head>
11     <body>
12         {% block body %}
13         {% endblock %}
14     </body>
15 </html>
```

Program 14.12: Layout HTML

```
1  {% extends "layout.html" %}
2
3  {% block body %}
4      <form action="/hello">
5          <input name="name" type="text">
6          <input type="submit">
7      </form>
8  {% endblock %}
```

Program 14.13: Requesting name in HTML that extends layout

```
1  {% extends "layout.html" %}
2
3  {% block body %}
4      Hello, {{ name }}!
5  {% endblock %}
```

Program 14.14: Displaying name in HTML that extends layout


```

1  {% extends "layout.html" %}
2
3  {% block style %}
4      body
5      {
6          color: red;
7      }
8  {% endblock %}
9
10 {% block body %}
11     You must provide a name!
12 {% endblock %}

```

Program 14.15: Failure message in HTML that extends layout

14.7 Tasks Application

```

1  from flask import Flask, redirect, render_template, request
2
3  app = Flask(__name__)
4
5  todos = []
6
7  @app.route("/")
8  def tasks():
9      return render_template("tasks.html", todos=todos)
10
11 @app.route("/add", methods=["GET", "POST"])
12 def add():
13     if request.method == "GET":
14         return render_template("add.html")
15     else:
16         todo = request.form.get("task")
17         todos.append(todo)
18         return redirect("/")

```

Program 14.16: Tasks Application using Flask

```

1  <!DOCTYPE html>
2
3  <html lang="en">
4      <head>
5          <title>Tasks</title>
6      </head>
7      <body>
8          {% block body %}
9          {% endblock %}
10     </body>
11 </html>

```

Program 14.17: Layout for the tasks application

```

1  {% extends "layout.html" %}
2
3  {% block body %}
4      <h1>Tasks</h1>
5      <ul>
6          {% for todo in todos %}
7              <li>{{ todo }}</li>
8          {% endfor %}
9      </ul>
10
11     <a href="/add">Create a New Task</a>
12 {% endblock %}

```

Program 14.18: Default page for the tasks application

```

1  {% extends "layout.html" %}
2
3  {% block body %}
4      <form action="/add" method="post">
5          <input id="task" name="task" type="text"
6              ↳ placeholder="Task Name">
7          <input id="submit" type="submit" disabled>
8      </form>
9      <script>
10         document.querySelector('#task').onkeyup = function() {
11             if (document.querySelector('#task').value === '') {
12                 document.querySelector('#submit').disabled =
13                     ↳ true;
14             } else {
15                 document.querySelector('#submit').disabled =
16                     ↳ false;
17             }
18         }
19     </script>
20 {% endblock %}

```

Program 14.19: Add page for the tasks application

Chapter 15

Databases

Can use cookies and databases to show personalized webpages.

15.1 Sessions

```
1 from flask import Flask, redirect, render_template, request,
   session
2 from flask_session import Session
3
4 app = Flask(__name__)
5 app.config["SESSION_PERMANENT"] = False
6 app.config["SESSION_TYPE"] = "filesystem"
7 Session(app)
8
9 todos = []
10
11 @app.route("/")
12 def tasks():
13     if "todos" not in session:
14         session["todos"] = []
15     return render_template("tasks.html",
16         session=session["todos"])
17
18 @app.route("/add", methods=["GET", "POST"])
19 def add():
20     if request.method == "GET":
21         return render_template("add.html")
22     else:
```

```

22         todo = request.form.get("task")
23         session["todos"].append(todo)
24         return redirect("/")

```

Program 15.1: Sessions in tasks application in Flask

15.2 SQL

```

1  from cs50 import SQL
2  from flask import Flask, redirect, request, render_template
3
4  app = Flask(__name__)
5
6  db = SQL("sqlite:///lecture.db")
7
8  @app.route("/")
9  def index():
10     rows = db.execute("SELECT * FROM registrants")
11     return render_template("index.html", rows=rows)
12
13  @app.route("/register", methods=["GET", "POST"])
14  def register():
15     if request.method == "GET":
16         return render_template("register.html")
17     else:
18         name = request.form.get("name")
19         if not name:
20             return render_template("apology.html", message="You
21                                     ↳ must provide a name.")
22         email = request.form.get("email")
23         if not email:
24             return render_template("apology.html", message="You
25                                     ↳ must provide a email.")
26         db.execute("INSERT INTO registrants (name, email)
27                     ↳ VALUES (:name, :email)", name=name, email=email)
28         return redirect("/")

```

Program 15.2: Register App using SQL database in Flask

```

1  <!DOCTYPE html>
2
3  <html lang="en">
4      <head>
5          <title>Registrants</title>
6      </head>
7      <body>
8          {% block body %}
9          {% endblock %}
10     </body>
11 </html>

```

Program 15.3: Layout of Register App

```

1  {% extends "layout.html" %}
2
3  {% block body %}
4      <h1>Registrants</h1>
5      <ul>
6          {% for row in rows %}
7              <li>{{ row["name"] }} ({{ row["email"] }})</li>
8          {% endfor %}
9      </ul>
10
11     <a href="/register">Register</a>
12 {% endblock %}

```

Program 15.4: Default page of Register App

```

1  {% extends "layout.html" %}
2
3  {% block body %}
4      <h1>Registrants</h1>
5
6      <form action="/register" method="post">
7          <input type="text" name="name" placeholder="Name">
8          <input type="email" name="email" placeholder="Email
           Address">
9          <input type="submit">
10     </form>
11 {% endblock %}

```

Program 15.5: Registration page of Register App

```

1  {% extends "layout.html" %}
2
3  {% block body %}
4      <h1>Sorry!</h1>
5
6      <div>
7          {{ message }}
8      </div>
9
10     <a href="/">Go Back</a>
11 {% endblock %}

```

Program 15.6: Apology page of Register App

Part III

Android

Chapter 16

Java

16.1 Introduction

Use Android Studio (IDE) to build android apps. Convention for package name is your domain name in reverse followed by app name. Use androidx (newer version android libraries). Also need to create AVD (Android Virtual Device) to simulate an android device to run your app. Use Java to code.

16.2 Data Types

- `boolean`
- `double, float`
- `char`
- `int`
- `List`
- `Map`
- `String`
- ...

16.3 Examples

```
1 String title = "CS50";  
2 int count = 50;
```

```

3  count += 5;
4
5  String title = "iOS";
6  if (title.equals("iOS")) {
7      System.out.println("Good Choice");
8  }
9  else {
10     System.out.println("Maybe Next Time");
11 }
12
13 int[] values = new int[]{1, 2, 3};
14 for (int i = 0; i < values.length; i++){
15     System.out.println(i);
16 }

```

Program 16.1: First few lines of java

16.4 Generics

16.4.1 Lists

```

1  List<String> values = new ArrayList<>();
2  values.add("one");
3  values.add("two");
4  for (String value : values){
5      System.out.println(value);
6  }

```

Program 16.2: Lists in java using Generics

16.4.2 Maps

```

1  Map<String, String> airports = new HashMap<>();
2  airports.put("SFO", "San Francisco");
3  airports.put("BOS", "Boston");
4  for (Map.Entry<String, String> e : airports.entrySet()) {
5      System.out.println(e.getKey() + ": " + e.getValue());
6  }

```

Program 16.3: Maps in java using Generics

16.5 Classes

structs + functions/methods = class

```
1 public class Person {
2     String name;
3
4     Person(String name) {
5         this.name = name;
6     }
7
8     public void sayHello() {
9         System.out.println("I'm " + name);
10    }
11 }
12
13 Person person = new Person("Tommy");
14 person.sayHello();
```

Program 16.4: Classes in java

16.6 Static Methods

Can be called from a class, without having an instance of it.

```
1 public class Person {
2     ...
3     public static void wave() {
4         System.out.println("Wave");
5     }
6 }
7
8 Person.wave();
```

Program 16.5: Static Methods in java

16.7 Inheritance

```
1 public class Vehicle {
2     public int wheels() {
3         return 4;
4     }
5
6     public void go() {
7         System.out.println("zoom!");
8     }
9 }
10
11 public class Motorcycle extends Vehicle {
12     @Override
13     public int wheels() {
14         return 2;
15     }
16 }
```

Program 16.6: Inheritance in Java Classes

16.8 Interfaces

Basically a list of methods to implement in classes. If we forget, compiler raises an error.

```
1 public interface Teacher() {
2     public void teach();
3 }
4
5 public class CS50Teacher implements Teacher {
6     @Override
7     public void teach() {
8         ...
9     }
10 }
```

Program 16.7: Interfaces in Java Classes

Remark. We can implement multiple interfaces but only extend one class.

16.9 Packages

Sort of a way to organise java code.

```
1 package edu.harvard.cs50.example;
2
3 import java.util.List;
```

Program 16.8: Packages in Java

16.10 Android

```
1 package com.example.javaexample;
2
3 public class House {
4     private String name;
5     private String head;
6
7     House(String name, String head){
8         this.name = name;
9         this.head = head;
10    }
11
12    public String getName(){
13        return name;
14    }
15
16    public String getHead(){
17        return head;
18    }
19 }
```

Program 16.9: House class in Java

```

1  package com.example.javaexample;
2
3  import androidx.appcompat.app.AppCompatActivity;
4
5  import android.os.Bundle;
6  import android.os.Trace;
7  import android.util.Log;
8
9  import java.util.ArrayList;
10 import java.util.Arrays;
11 import java.util.HashMap;
12 import java.util.List;
13 import java.util.Map;
14 import java.util.Random;
15
16 public class MainActivity extends AppCompatActivity {
17
18     @Override
19     protected void onCreate(Bundle savedInstanceState) {
20         super.onCreate(savedInstanceState);
21         setContentView(R.layout.activity_main);
22
23         List<House> houses = new ArrayList<>();
24         houses.add(new House("Gryffindor", "McGonagall"));
25         houses.add(new House("Hufflepuff", "Sprout"));
26         houses.add(new House("Ravenclaw", "Flitwick"));
27         houses.add(new House("Slytherin", "Snape"));
28
29         List<String> students = Arrays.asList("Harry", "Ron",
30             "Hermione", "Neville", "Draco", "Parvati", "Padma",
31             "Cho", "Cedric");
32         Map<String, House> assignments = new HashMap<>();
33
34         Random random = new Random();
35         for (String student : students) {
36             int index = random.nextInt(houses.size());
37             assignments.put(student, houses.get(index));
38         }
39     }
40 }

```

```

38     for (Map.Entry<String, House> entry :
        ↪ assignments.entrySet()) {
39         House house = entry.getValue();
40         Log.d("cs50", entry.getKey() + " got " +
            ↪ house.getName() + " under " + house.getHead());
41     }
42 }
43 }

```

Program 16.10: Example Android Application in Java

Chapter 17

UI

17.1 Gradle

Open Source Project - an Android Build System!

17.2 MVC

Model - View - Controller.

Design Pattern that advocates separating out the app in three different pieces.

17.3 Activities

Sort of a base class for a screen.

17.4 Resources

All the stuff that isn't code! Example? Layout!

17.5 Layouts

A layout describes how a view should look. Defined using XML.

17.6 XML

eXtensible Markup Language.


```

1 <LinearLayout>
2 <TextView android:text="Hello" />
3 </LinearLayout>

```

Program 17.1: sample XML code

17.7 Intent

Special object that represents a way to go from one activity to another.

17.8 RecyclerView

It basically represents anything that's a list of items.

17.9 App Files

From our *Pokedex* App.

17.9.1 Manifests

AndroidManifest.xml

Basically a configuration file.

```

1 <?xml version="1.0" encoding="utf-8"?>
2 <manifest
3   xmlns:android="http://schemas.android.com/apk/res/android"
4   package="edu.harvard.cs50.pokedex">
5
6   <application
7     android:allowBackup="true"
8     android:icon="@mipmap/ic_launcher"
9     android:label="@string/app_name"
10    android:roundIcon="@mipmap/ic_launcher_round"
11    android:supportRtl="true"
12    android:theme="@style/AppTheme">
13      <activity android:name=".PokemonActivity"></activity>
14      <activity android:name=".MainActivity">
        <intent-filter>

```

```

15         <action
            ↪ android:name="android.intent.action.MAIN"
            ↪ />
16
17         <category
            ↪ android:name="android.intent.category.LAUNCHER"
            ↪ />
18     </intent-filter>
19 </activity>
20 </application>
21
22 <uses-permission android:name="android.permission.INTERNET"
    ↪ />
23 </manifest>

```

Program 17.2: App Files : Manifests : AndroidManifest.xml

17.9.2 Java Codes

Code like we've seen before.

17.9.3 Layouts

```

1 <?xml version="1.0" encoding="utf-8"?>
2 <androidx.constraintlayout.widget.ConstraintLayout
    ↪ xmlns:android="http://schemas.android.com/apk/res/android"
3     xmlns:app="http://schemas.android.com/apk/res-auto"
4     xmlns:tools="http://schemas.android.com/tools"
5     android:layout_width="match_parent"
6     android:layout_height="match_parent"
7     tools:context=".MainActivity">
8
9     <androidx.recyclerview.widget.RecyclerView
10         android:layout_width="match_parent"
11         android:layout_height="match_parent"
12         android:id="@+id/recycler_view" />
13
14 </androidx.constraintlayout.widget.ConstraintLayout>

```

Program 17.3: App Files : Layouts : activity_main.xml

17.9.4 Values

strings.xml

Helps when we want to support multiple languages.

```
1 <resources>
2     <string name="app_name">Pokedex</string>
3 </resources>
```

Program 17.4: App Files : Values : strings.xml

17.9.5 Gradle Scripts

```
1 apply plugin: 'com.android.application'
2
3 android {
4     compileSdkVersion 28
5     buildToolsVersion "29.0.2"
6     defaultConfig {
7         applicationId "edu.harvard.cs50.pokedex"
8         minSdkVersion 21
9         targetSdkVersion 28
10        versionCode 1
11        versionName "1.0"
12        testInstrumentationRunner
13            ↪ "androidx.test.runner.AndroidJUnitRunner"
14    }
15    buildTypes {
16        release {
17            minifyEnabled false
18            proguardFiles
19                ↪ getDefaultProguardFile('proguard-android-optimize.txt'),
20                ↪ 'proguard-rules.pro'
21        }
22    }
23 }
24
25 dependencies {
26     implementation fileTree(dir: 'libs', include: ['*.jar'])
27     implementation 'androidx.appcompat:appcompat:1.1.0'
```

```

25     implementation
      ↪ 'androidx.constraintlayout:constraintlayout:1.1.3'
26     implementation 'androidx.recyclerview:recyclerview:1.0.0'
27     implementation 'com.android.volley:volley:1.1.1'
28
29     testImplementation 'junit:junit:4.12'
30     androidTestImplementation 'androidx.test:runner:1.2.0'
31     androidTestImplementation
      ↪ 'androidx.test.espresso:espresso-core:3.2.0'
32 }

```

Program 17.5: App Files : Gradle Scripts : build.gradle (Module app)

17.10 Adding Recycler View

1. Add dependency in build.grade (Module: App)
2. Start with view - What the app needs to be doing
 - (a) Add view in the layout (activity_main.xml)
 - (b) Add ID to the view to reference
 - (c) Need a way to define how each row is going to look like
 - (d) Create new layout for that
 - (e) Add view in this layout, and IDs to reference
3. Then create models to power that view
 - (a) Create java class to represent a single element
 - (b) Add constructors, getters, and setters as per need
4. Write the controllers to hook up the two
 - (a) Recycler class has another class attached to it called the adapter - what data is to be displayed and how to do it
 - (b) Create class to represent all of the data inside the recycler view that extends `RecyclerView.Adapter`
 - (c) It's a generic class that takes as its type a *ViewHolder* that holds a view and allows to manipulate what's on the screen. We're going to create an object that holds that view and from there we modify some of the layout elements we just defined

- (d) Add fields in the ViewHolder class to represent the layout and views we created
 - (e) Write constructors to get views by id
 - (f) Get data (or hardcode some for now)
 - (g) Implement methods defined on RecyclerView.Adapter
 - i. onCreateViewHolder
 - ii. onBindViewHolder
 - iii. getItemCount
5. Use the adapter
- (a) Add a few more fields in the MainActivity
 - i. RecyclerView
 - ii. RecyclerView.Adapter
 - iii. RecyclerView.LayoutManager
 - (b) Instantiate them
 - (c) Connect them

17.11 Adding New Activity

1. Create New Activity (right click on left hand side)
2. Start with layout
3. Next is model
4. Now *Intent*, that is how we pass data from first activity to the second
 - (a) Use containerView.setTag and pass the object representing the data
 - (b) Add eventHandler

Chapter 18

API

Application Programming Interface

18.1 JSON

JavaScript Object Notation

18.2 Volley

Library provided by Google and Android to make internet API calls.

18.3 Try, Catch

Exceptions!

```
1  try {  
2      object.something();  
3  }  
4  catch (Exception e) {  
5      e.printStackTrace();  
6  }
```

Program 18.1: Try, Catch in Java

18.4 Permissions

Don't forget to mention permissions in AndroidManifest.xml

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