Loops: for loops & while loops

- Using a loop to solve a problem is called *iteration*.

- *while* is similar to *if* statements but *while* repeatedly "loops back" and executes the *statement* until the *expression* is false.

- General format of a *while* loop:

  ```
  setup statement(s)
  while (expression) {
    body statement(s)
    update statement(s)
  }
  ```

- *for* loops are a "condensed" version of a *while* loop.

for vs. while

Recall the *for* syntax.

```for (setup; expression; update) { body statement(s) }
```  

This *while* example

```i = 100; // setup
while (i >= 0) { // expression
  printf("%d\n", i);
  --i; // update
}
```  

is equivalent to

```for (i = 100; i >= 0; --i) {
  printf("%d\n", i);
}
```
Loop: Exercise

Define the following C function: (use iteration)

```c
// draw_circle(size) draws a circle inside of a square
// with dimensions (size * 2 + 1)
// requires: size >= 1
// effects: produces output

• There is a simple example of the output in "simple.expect"
```

Integer Overflow: Introduction

• Any variable in C takes up a certain amount of memory (bits).

• This limits the range of values that can be represented.

• Any time you try to go past this limit it is called an “overflow”

Integer Overflow

• A variable of type `int` allocates 32 bits of memory.

• We want to be able to represent negative and positive numbers, so roughly half of this range is negative and roughly half is positive.

• Using this logic, Integers range from $-2^{31}$ to $2^{31} - 1$, or $-2147483648$ to $2147483647$
Overflow

As an INT it is impossible to represent outside of the range of:

<table>
<thead>
<tr>
<th></th>
<th>(-2^{31})</th>
<th>(-2147482648)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INT_MIN</td>
<td>(-2^{31})</td>
<td>(-2147482648)</td>
</tr>
<tr>
<td>INT_MAX</td>
<td>(2^{31} - 1)</td>
<td>(2147482647)</td>
</tr>
</tbody>
</table>

which is why we have other data-types

Integer Overflow Example

The following function can overflow for large values of a and b.

```c
// find_mid(low, high): returns the middle integer between
// two boundaries, low and high, inclusively
// [round down to the whole integer]
// Requires: 0 <= low <= high
int find_mid(int low, int high) {
    return (low + high) / 2;
}
```

Even though it can never return a number larger than INT_MAX, the result of computing \((a + b)\) is undetermined.

Practice: On seashell, implement the `find_mid` function that would fix the issue above

Practice Problem: Overflow

The function `not Overflow_add(a, b)` returns true if adding non-negative integers a and b will not cause overflow, otherwise, returns false.

For example,

```c
not Overflow_add(1, 0); // => true
not Overflow_add(INT_MAX, 1); // => false
```
## Data Types

<table>
<thead>
<tr>
<th>Variable Type</th>
<th>Description</th>
<th>Printf</th>
</tr>
</thead>
<tbody>
<tr>
<td>int</td>
<td>Integer (numbers)</td>
<td>%d</td>
</tr>
<tr>
<td>char</td>
<td>Characters</td>
<td>%c</td>
</tr>
<tr>
<td>float</td>
<td>Floating Point decimal numbers</td>
<td>%f</td>
</tr>
<tr>
<td>double</td>
<td>Double precision floating value</td>
<td>%f</td>
</tr>
</tbody>
</table>

### Characters

Characters are **integers** that are typically used to hold single pieces of text data. They are 8-bit (max value of 127).

```c
char nine = '9';
char not_nine = 9;  // Be careful! This is a tab!
char a = 'a';
char also_a = 97;   // Equivalent, but bad practice.
char space = ' ';   // Some characters use escape codes.
char newline = '\n';
```

Later on, we will learn how to use a series of characters in a row to represent more complicated text like words and sentences.

### Debugging Tips

- **Use trace statements:**
  - Print out the values of variables.
  - Print out statements to show control flow.
- **Automate:**
  - Write your own tests!
- **Simplify:**
  - Comment out parts that aren’t a likely cause.
  - Remove components until you isolate the problem.
  - Writing modular code helps immensely.