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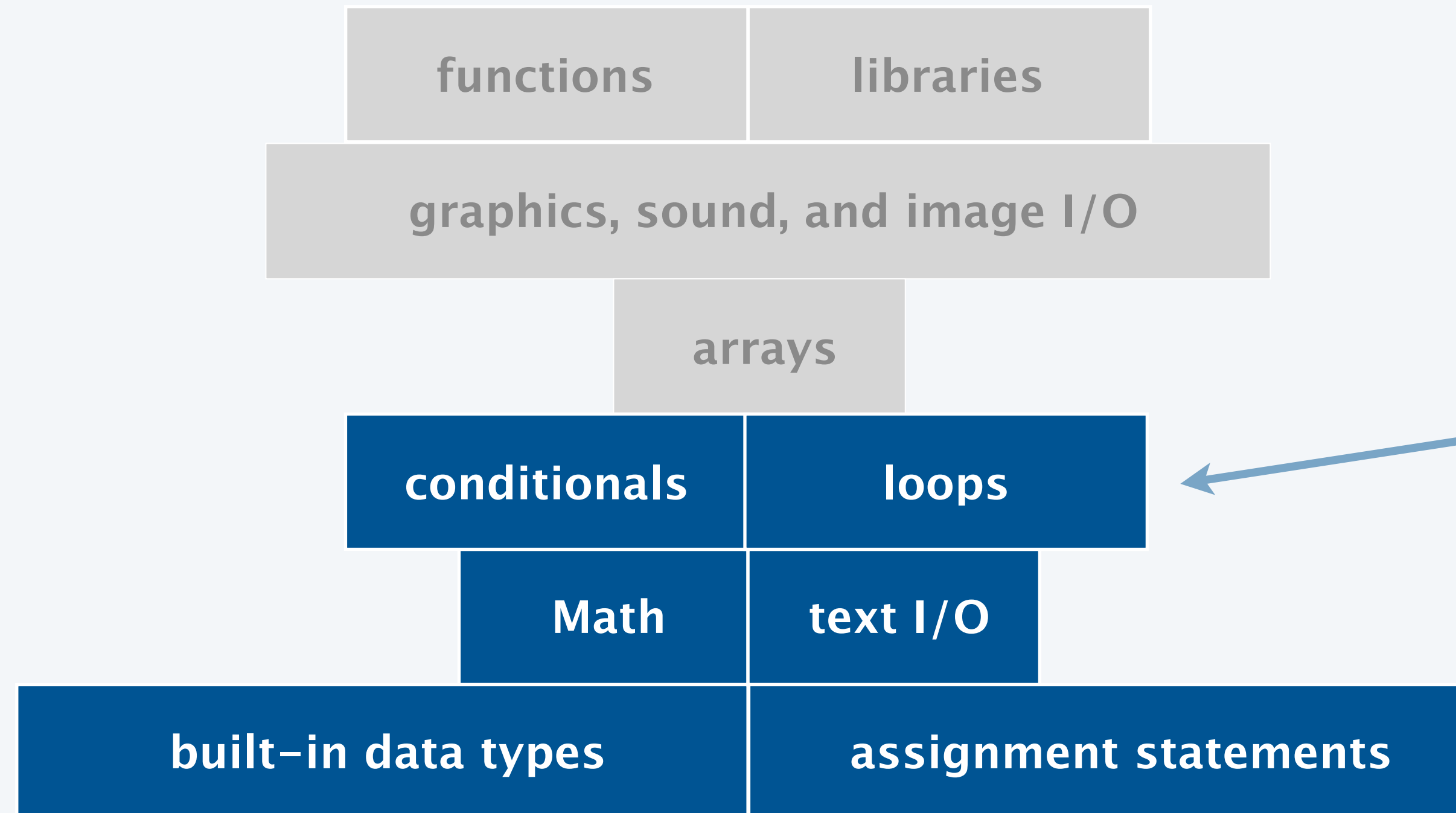
## 1.3 LOOPS

---

- ▶ *while loops*
- ▶ *do-while loops*
- ▶ *for loops*
- ▶ *nested loops*
- ▶ *image processing*

# Basic building blocks for programming

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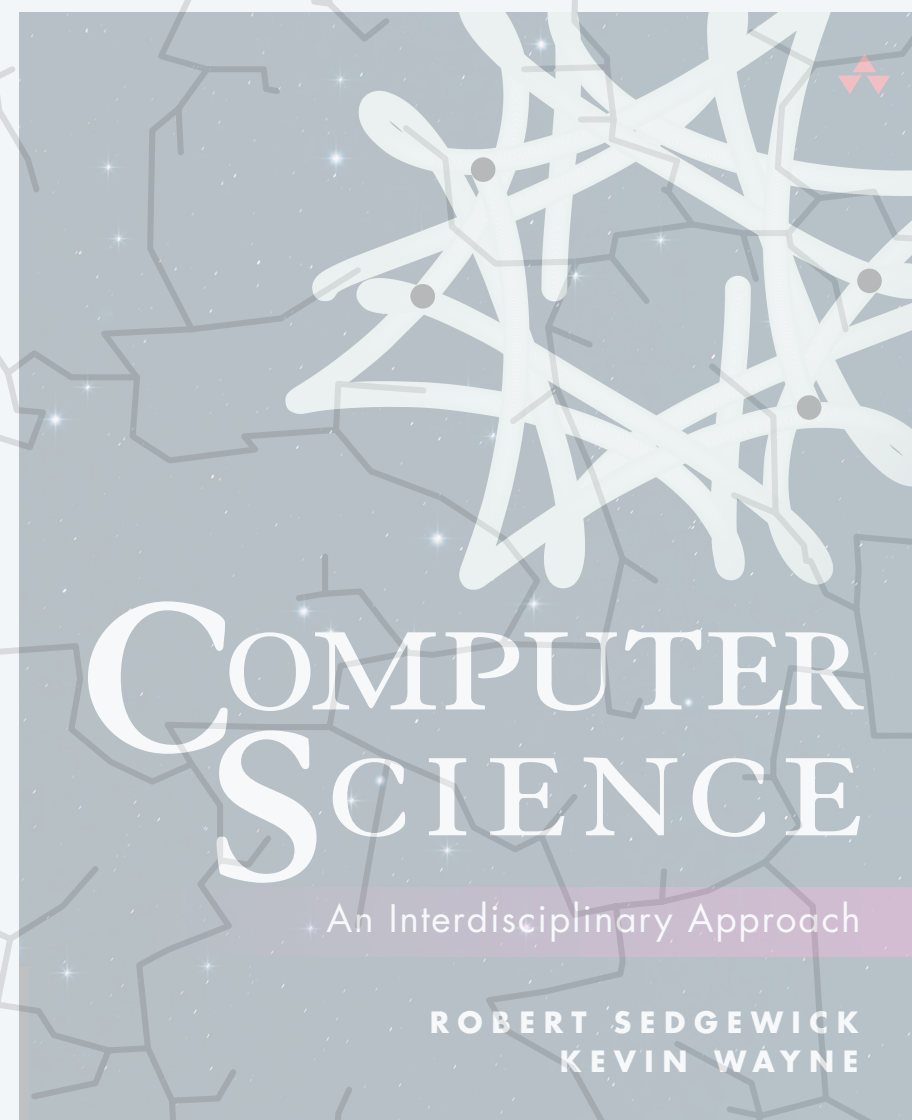


*to infinity and beyond !*

## *Review*

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- 1) What are conditional statements?
- 2) What are the rules around if, else if, and else usage?
- 3) What happens if one of the conditional statements is evaluated to true?



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## 1.3 LOOPS

---

- ▶ *while loops*
- ▶ *do-while loops*
- ▶ *for loops*
- ▶ *nested loops*
- ▶ *image processing*

# Loops

## Actions or statements that repeat

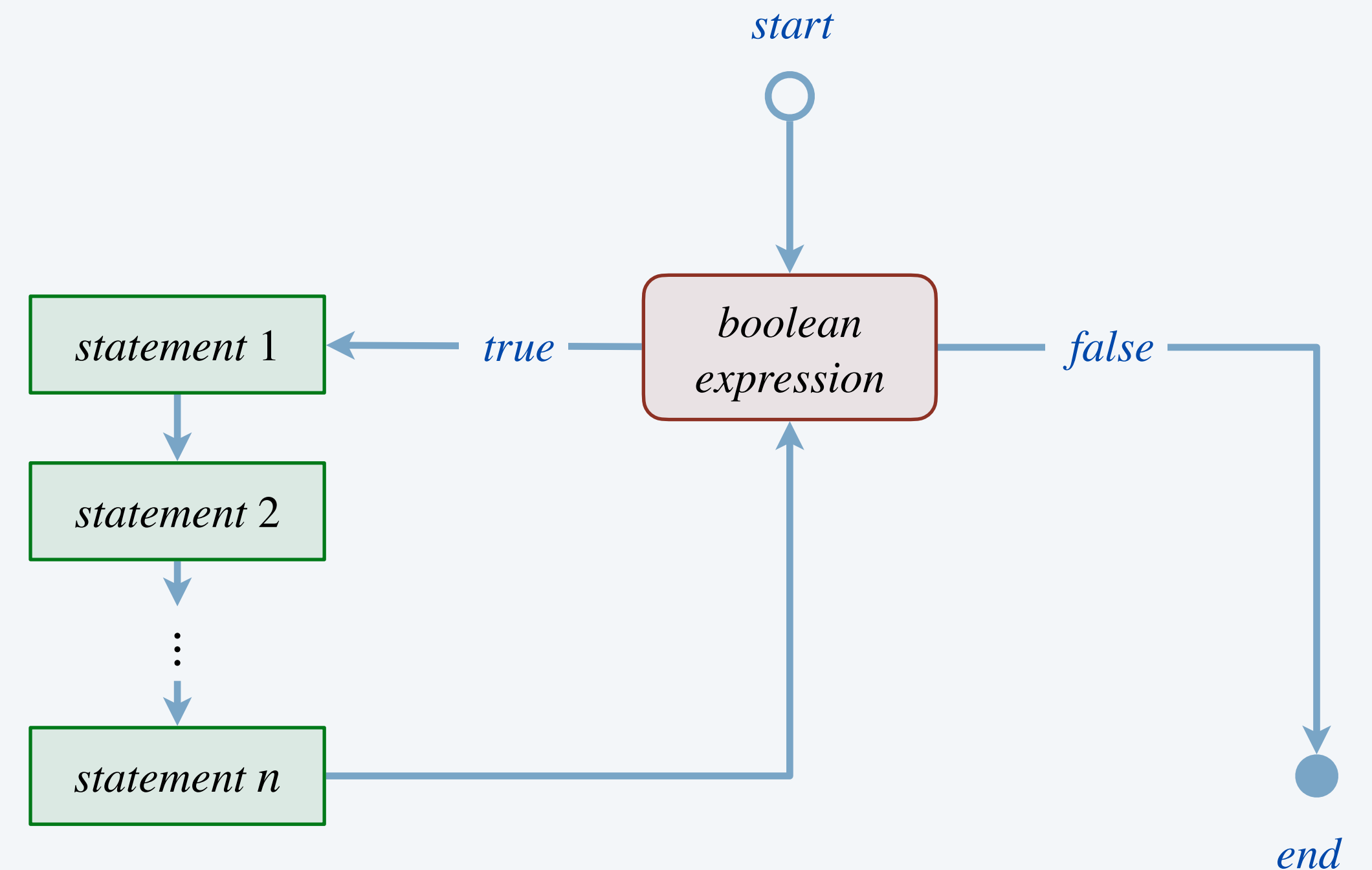
- e.g., “End on a win” -> “As long as we keep losing, keep playing”
- Pseudocode:

```
while (weLost == true) {  
    keepPlaying...  
}
```

*loop-continuation condition*

```
while (<boolean expression>) {  
    <statement 1>  
    <statement 2>  
    ⋮  
    <statement n>  
}
```

while loop

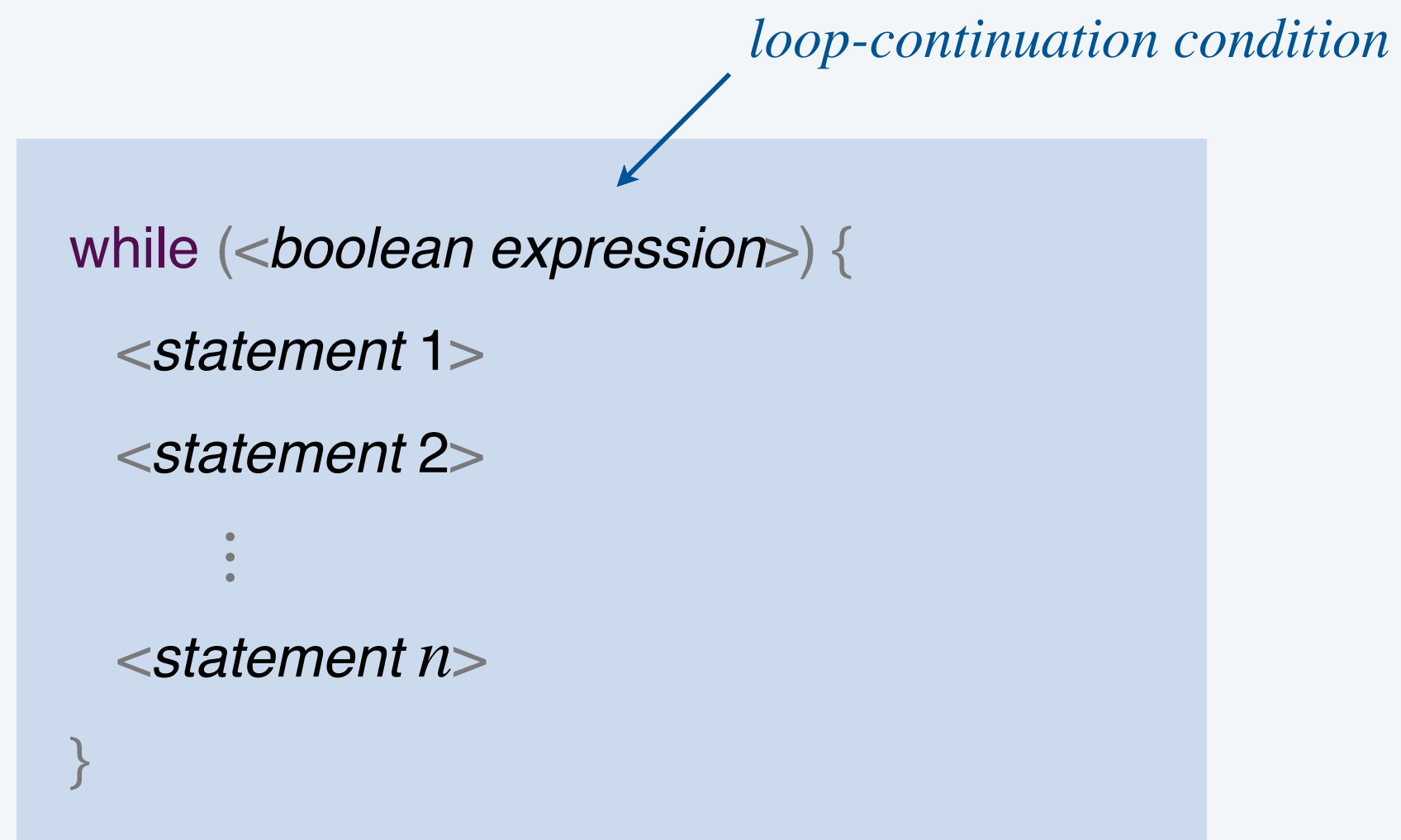


while loop flow chart

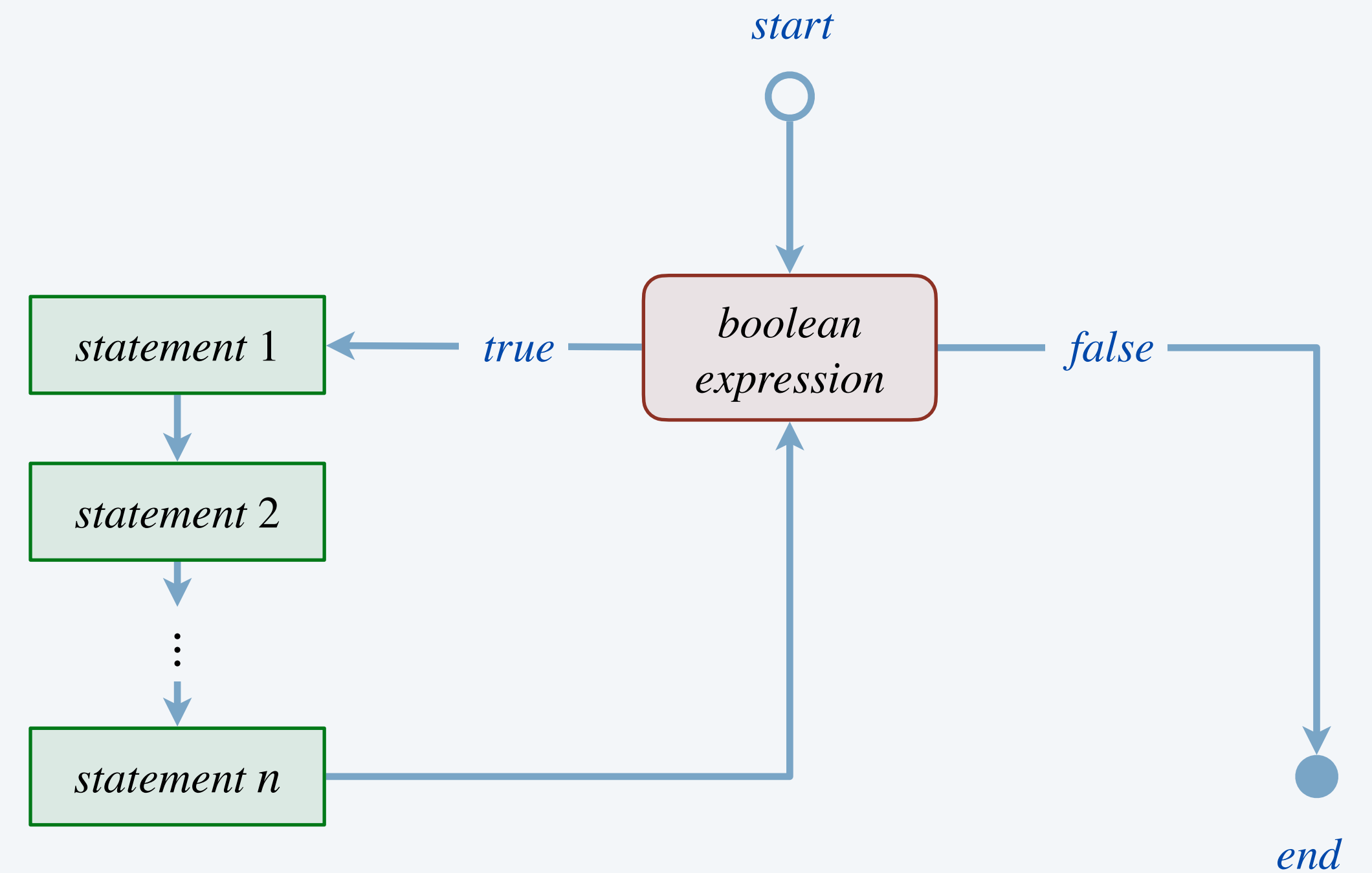
# The *while* loop

**Goal.** Repeat a certain statement (or statements).

- Evaluate a **boolean expression**. If *true*,
  - execute sequence of statements in **code block**
  - repeat



while loop



while loop flow chart

# Loops

---

## Actions or statements that repeat

- e.g., “End on a win” -> “As long as we keep losing, keep playing”

- Pseudocode:

```
while (weLost == true) {  
    keepPlaying...  
}
```

# Loops

---

## Actions or statements that repeat

- e.g., “End on a win” -> “As long as we keep losing, keep playing”

- Pseudocode:

```
while (weLost == true) {  
    keepPlaying...  
}
```

- Indefinite – *How many more games will we play? We don't know*

# Loops

---

## Actions or statements that repeat

- e.g., “End on a win” -> “As long as we keep losing, keep playing”

- Pseudocode:

```
while (true) {  
    keepPlaying...  
}
```

- What if we never wanted to stop?

# Loops


---

## Actions or statements that repeat

- e.g., “End on a win” -> “As long as we keep losing, keep playing”

- Pseudocode:

```
while (true) {  
    keepPlaying...  
}
```

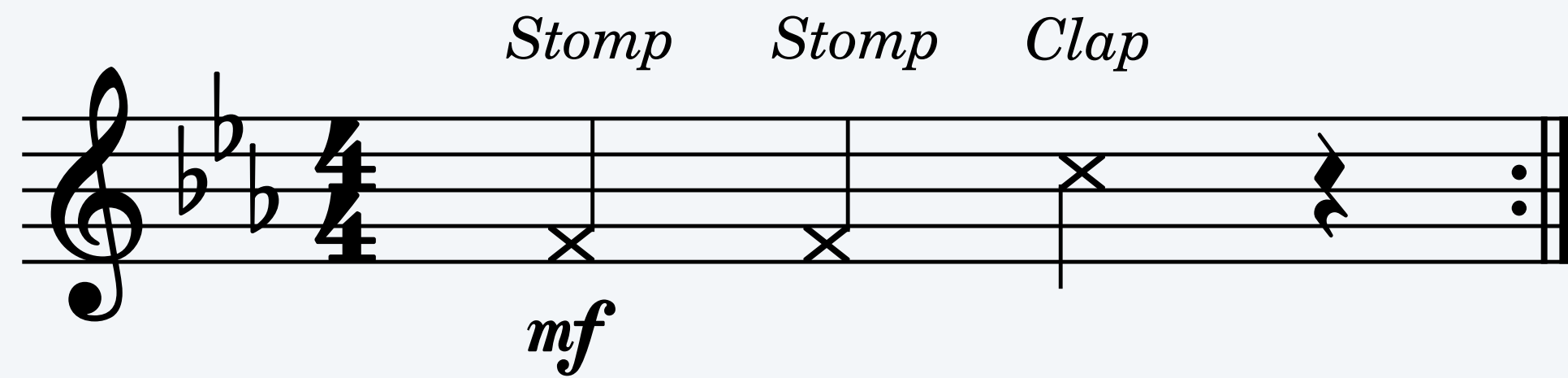
← *Infinite loop*  


- What if we never wanted to stop?
  - Infinite loop

# An infinite *while* loop



**Goal.** Recreate percussive beat from Queen's "*We Will Rock You.*"



effect	audio file	sound
<i>stomp</i>	stomp.wav	
<i>clap</i>	clap.wav	
<i>silence</i>	rest.wav	

```
public class StompStompClap {  
    public static void main(String[] args) {  
  
        while (true) {  
            StdAudio.play("stomp.wav");  
            StdAudio.play("stomp.wav");  
            StdAudio.play("clap.wav");  
            StdAudio.play("rest.wav");  
        }  
    }  
}
```

← an infinite loop



```
~/cos126/loops> java-introcs StompStompClap
```

[plays stomp-stomp-clap beat]

← <Ctrl-C> to break out of infinite loop

# Counting from 1 to n



**Goal.** Repeat a ringtone  $n$  times (Definite loop).

**Trace.** Show values of variables at end of each iteration of *while* loop.

```
public class Ringtone {  
    public static void main(String[] args) {  
        String filename = args[0];  
        int n = 3;  
        int i = 0;  
        while (i < n) {  
            StdAudio.play(filename);  
            i++;  
        }  
    }  
}
```

← *Definite Loop*

← *shorthand for*  
 $i = i + 1$

<i>filename</i>	<i>n</i>	<i>i</i>	
"marimba.wav"	3	0	← <i>before loop</i>
🔊 "marimba.wav"	3	1	
🔊 "marimba.wav"	3	2	
🔊 "marimba.wav"	3	3	← <i>after loop</i>

**a trace of variables**  
**(values at end of each loop iteration)**

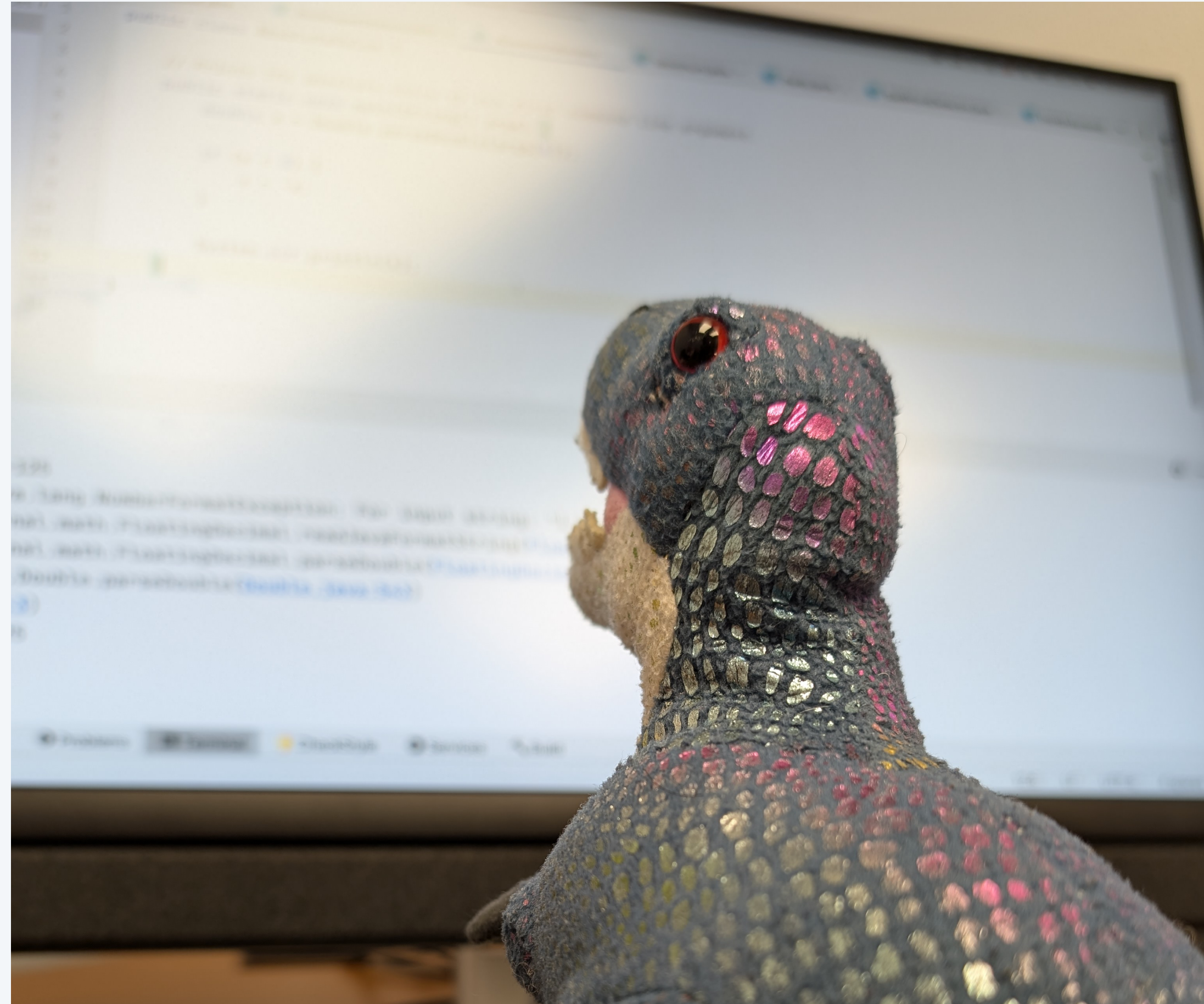


What does the following program do when  $n = 10$ ?

- A. Prints 0 to 10.
- B. Prints even numbers, from 0 to 10.
- C. Prints squares, from 0 to 10.
- D. Prints powers of 2, from  $2^0$  to  $2^{10}$ .
- E. None of the above.

```
public class Mystery {  
    public static void main(String[] args) {  
        int n = Integer.parseInt(args[0]);  
        int i = 0;  
        int value = 0;  
  
        while (value <= n) {  
            System.out.println(value);  
            value += 2 * i + 1;  
            i++;  
        }  
    }  
}
```

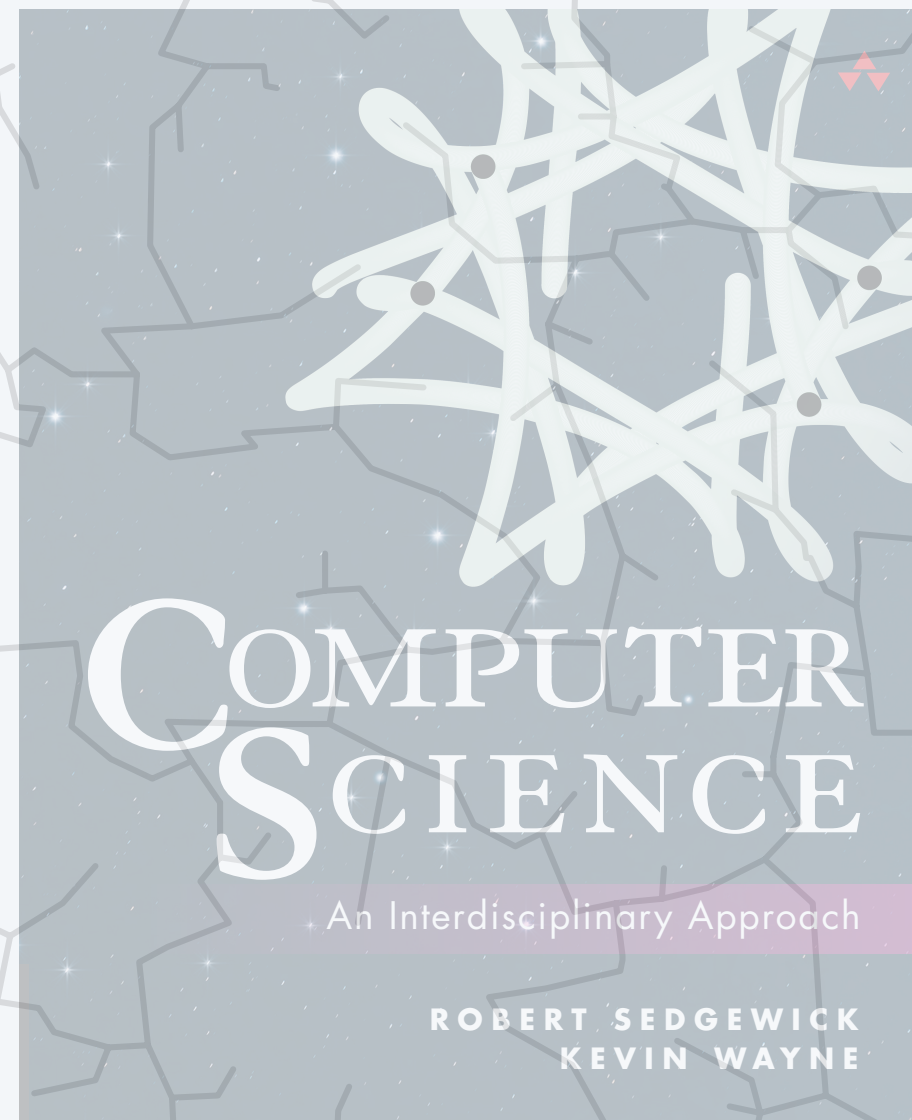
*shorthand for value = value + (2 \* i + 1)*



# Examples of *while* loops

computation	while loop
<i>Indefinite (Uncountable)</i>	<pre>int x = 0; while (x != 1) {     x = (int) (Math.random() * 6); }</pre>
<i>Infinite loop</i>	<pre>while (true) {     StdAudio.play("heartbeat.wav"); }</pre>
<i>Definite (Countable)</i>	<pre>int i = 10; while (i &gt; 0) {     System.out.println(i);     i--; }</pre> <p><i>shorthand for</i> <code>i = i - 1</code></p>

*curly braces are optional here  
since only one statement in body of loop  
(but better style to use curly braces)*



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## LOOPS

---

- ▶ *while loops*
- ▶ *do-while loops*
- ▶ *for loops*
- ▶ *nested loops*
- ▶ *image processing*

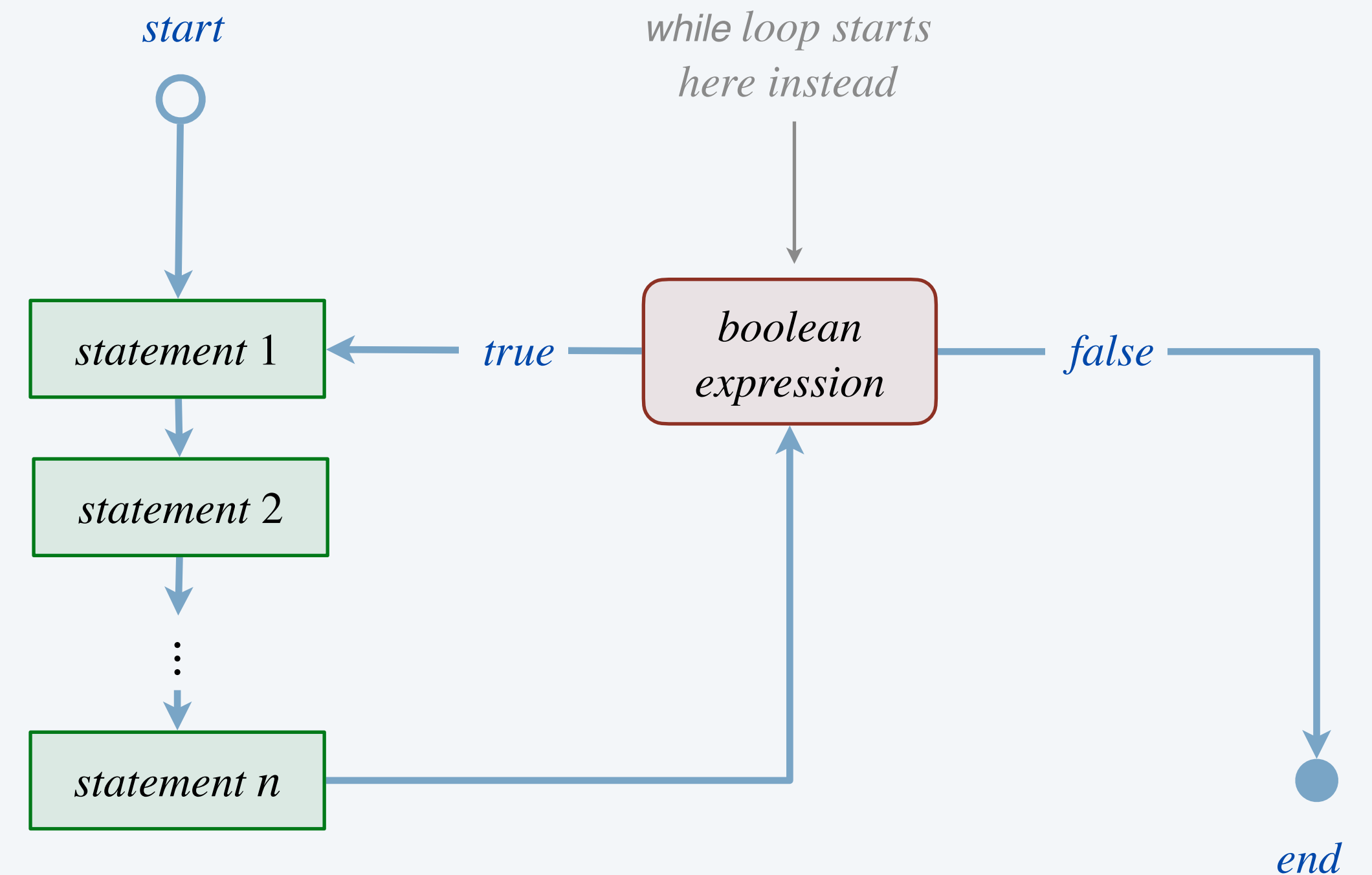
# The *do-while* loop

Another repetition structure.

- Execute a sequence of statements.
- Repeat until some *boolean expression* is false.

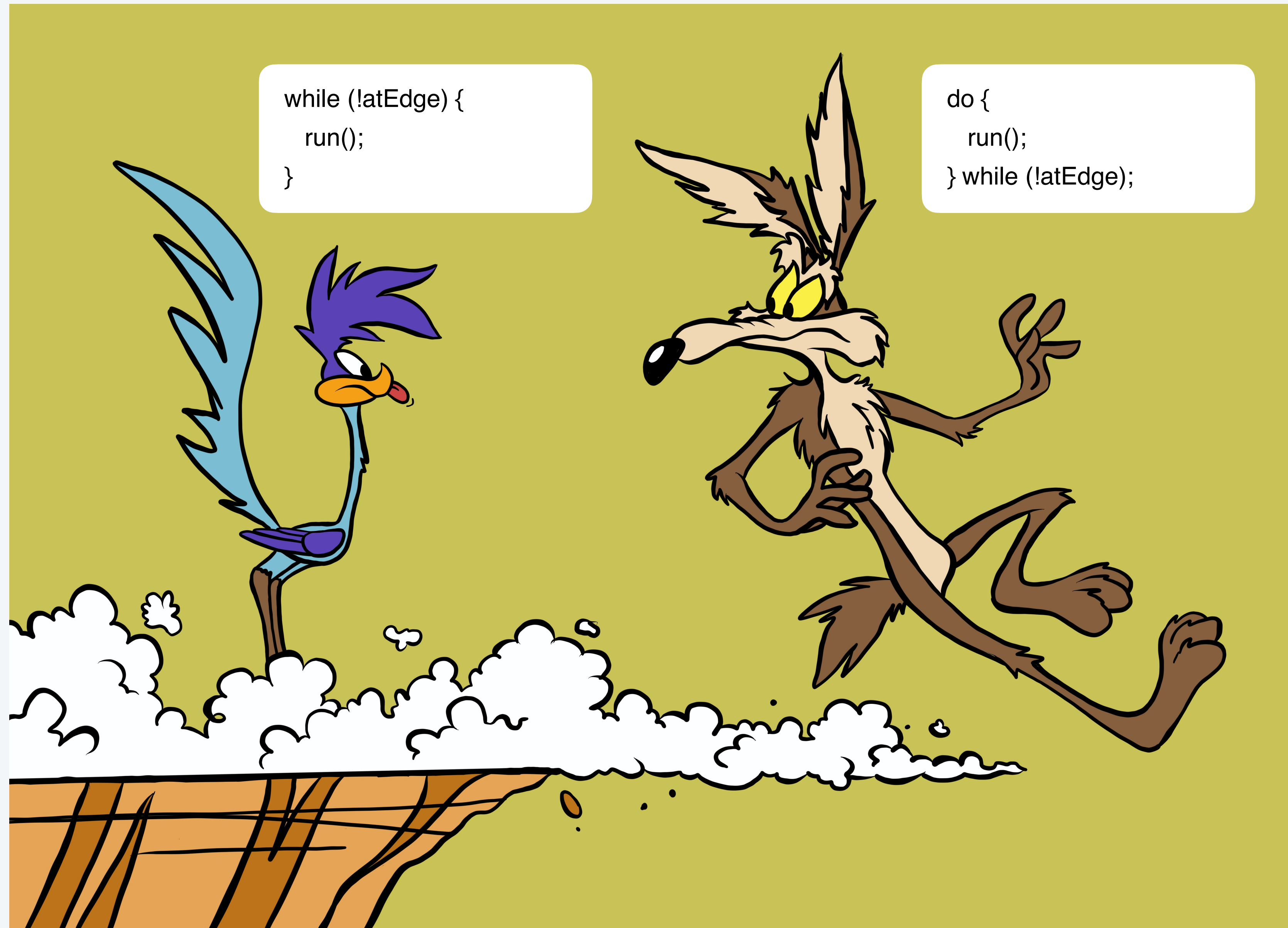
```
do {  
  <statement 1>  
  <statement 2>  
  ⋮  
  <statement n>  
} while (<boolean expression>;
```

do-while loop



do-while loop flow chart

# Wile E. Coyote and Road Runner

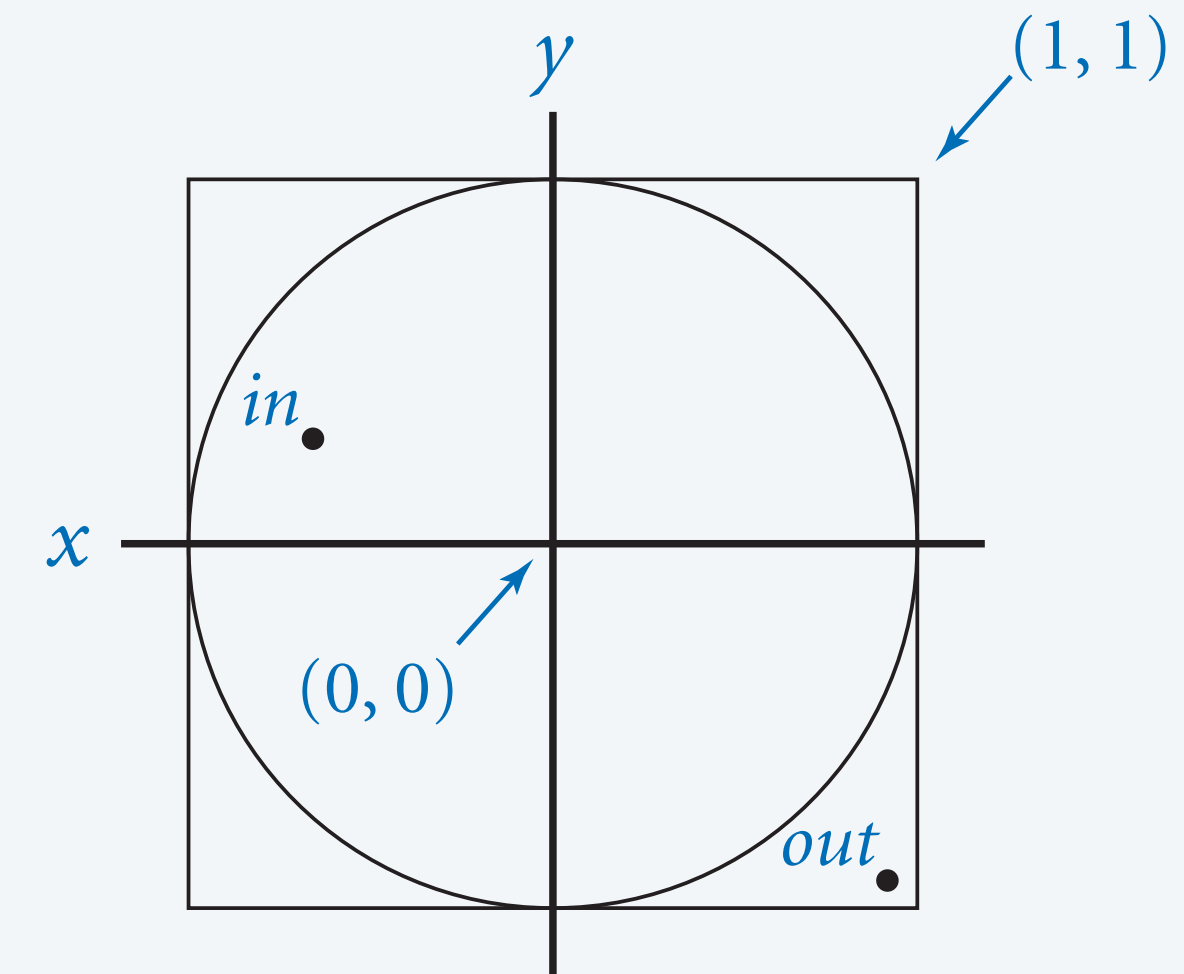


# Random point in unit circle

**Goal.** Generate a random point in unit circle.

**Rejection sampling.**

- Generate a random point in 2-by-2 square centered at origin.
- If point is inside circle, use that point; otherwise, repeat.



```
double x, y; ← must be declared outside block
```

```
do {
```

```
  x = 2.0 * Math.random() - 1.0;
```

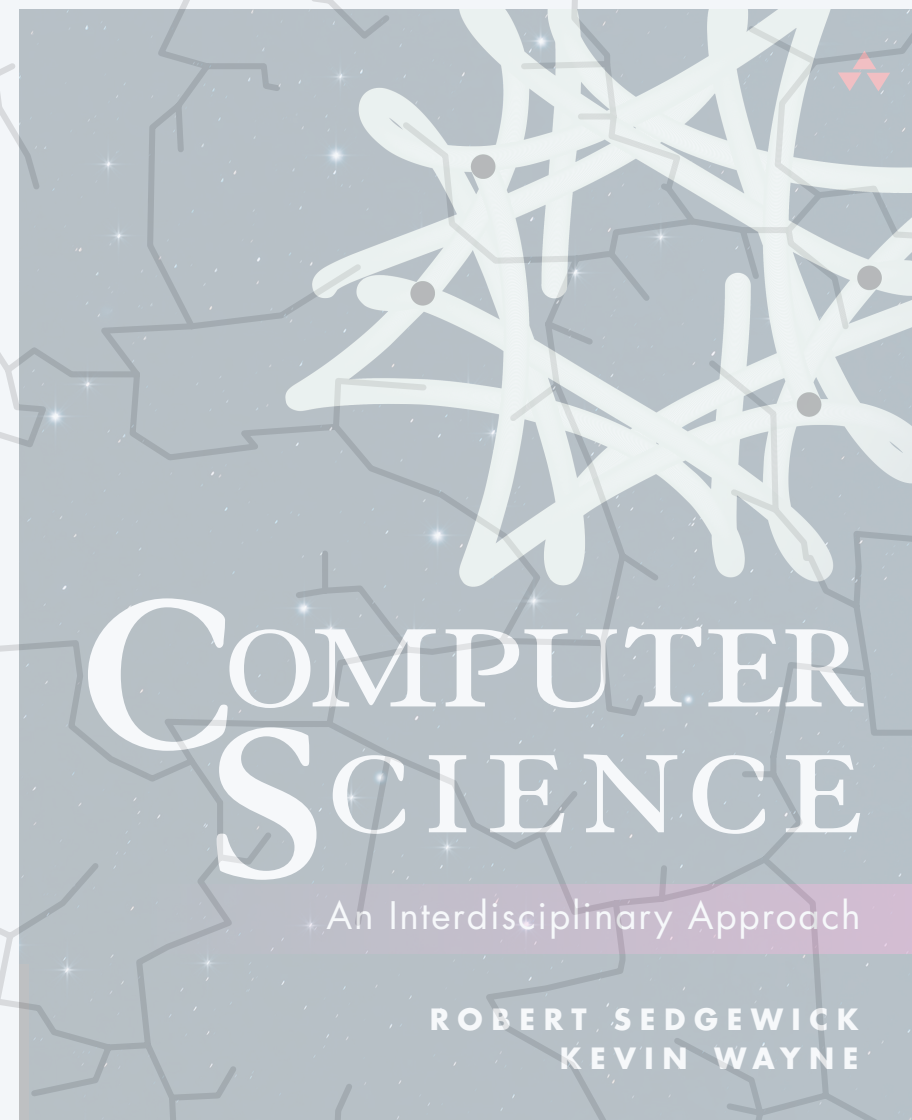
```
  y = 2.0 * Math.random() - 1.0;
```

```
} while (x*x + y*y > 1.0);
```

← random (x, y) in square

← repeat until it's in the circle

**do-while loop**



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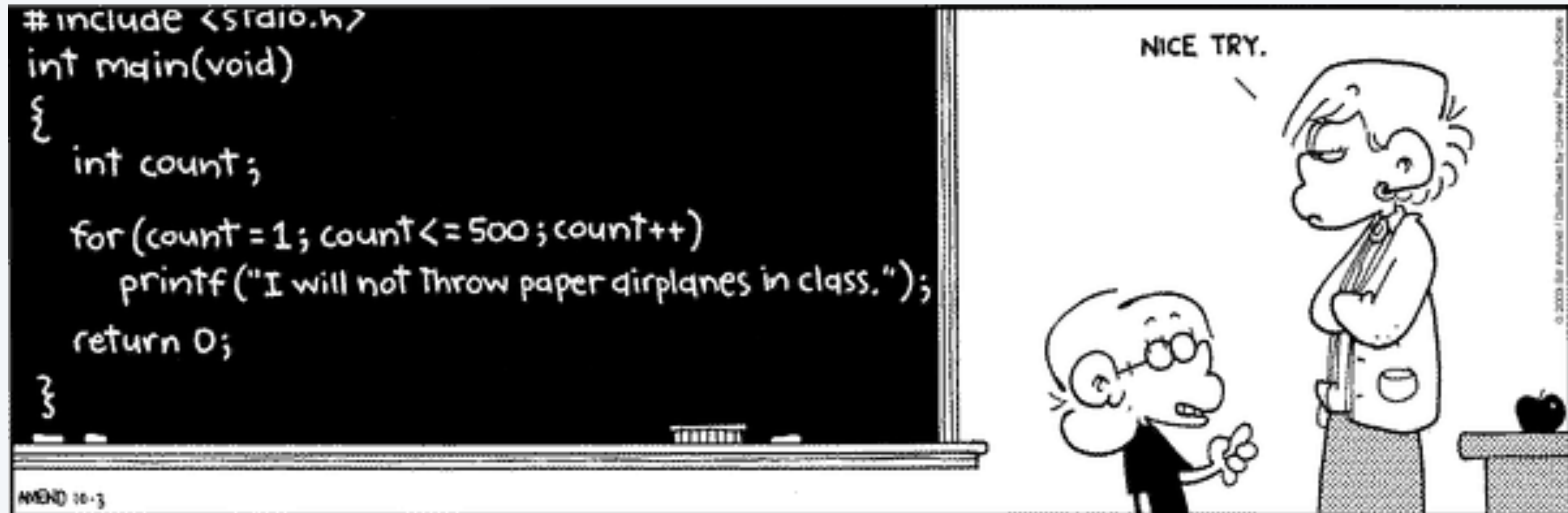
## LOOPS

---

- ▶ *while loops*
- ▶ *do-while loops*
- ▶ *for loops*
- ▶ *nested loops*
- ▶ *image processing*

## A for loop (in C)

---



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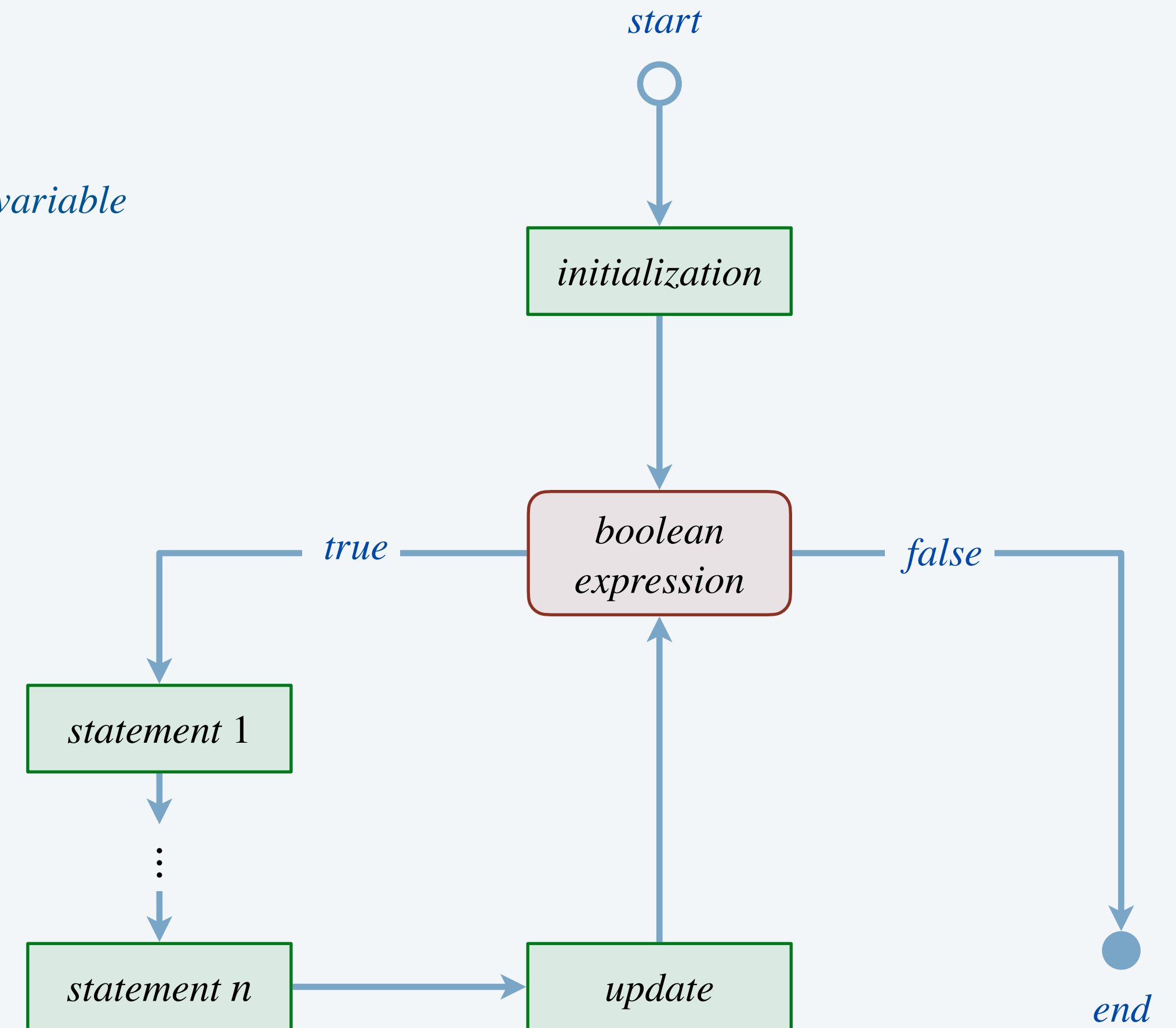
# The *for* loop

An alternative repetition structure.

- Perform an **initialization** step. ← typically, declaring and initializing the value of a variable
- Evaluate a **boolean expression**. If *true*,
  - execute sequence of statements in code block
  - perform an **update** step ← typically, updating the value of a variable
  - repeat

```
for (<init>; <boolean expression>; <update>) {  
  <statement 1>  
  <statement 2>  
  ⋮  
  <statement n>  
}
```

for loop



for loop flowchart

# Counting from 1 to n



Goal. Play a WAV file  $n$  times. ← *identical behavior as Ringtone.java*

```
public class MusicLoop {
    public static void main(String[] args) {
        String filename = args[0];
        int n = Integer.parseInt(args[1]);

        for (int i = 0; i < n; i++) {
            StdAudio.play(filename);
        }
    }
}
```

*repeat n times*

```
~/cos126/loops> java-introcs MusicLoop heartbeat.wav 1
```

🔊 [plays heartbeat once]

```
~/cos126/loops> java-introcs MusicLoop heartbeat.wav 9999999
```

🔊 [plays heartbeat repeatedly]

```
~/cos126/loops> java-introcs MusicLoop AmenBreak.wav 10
```

🔊 [plays The Winstons "Amen Break" drum break 10 times]

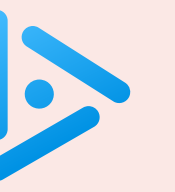
*among most sampled tracks  
in music history*

# Examples of *for* loops

computation	for loop
<i>factorial</i> $(1 \times 2 \times 3 \times \dots \times n)$	<pre>int product = 1; for (int i = 2; i &lt;= n; i++) {     product *= i; }</pre>
<i>print integers</i> <i>from n down to 1</i>	<pre>for (int i = n; i &gt; 0; i--) {     System.out.println(i); }</pre>
<i>infinite loop</i>	<pre>for (;;) {     StdAudio.play("heartbeat.wav"); }</pre>

← curly braces are optional since  
if body consists of only one statement  
(but better style to include)

← empty initialization and update  
(but better style to use while loop)



**Q.** Which value does the following program print when  $n = 3$ ?

- A.** 8
- B.** 64
- C.** 256
- D.** 512
- E.** 1024

```
public class AnotherMystery {  
    public static void main(String[] args) {  
        int n = Integer.parseInt(args[0]);  
  
        long result = 2;  
        for (int i = 0; i < n; i++)  
            result = result * result;  
  
        System.out.println(result);  
    }  
}
```

## Two special loop keywords



- `break` - used to exit encapsulating loop immediately
- `continue` - used to skip to next iteration immediately
  - Use both with caution
  - Strive for legibility

```
// Roll two dice until snake eyes found
int die = 0;
int die = 0;
while (die1 != 1 || die2 != 1) {
    die1 = (int) (Math.random() * 6) + 1;
    die2 = (int) (Math.random() * 6) + 1;
    System.out.println(die1 + " " + die2);
}
System.out.println("Snake eyes!");
```

```
// Roll two dice until snake eyes found
while (true) {
    int die1 = (int) (Math.random() * 6) + 1;
    int die2 = (int) (Math.random() * 6) + 1;
    System.out.println(die1 + " " + die2);
    if (die1 == 1 && die2 == 1)
        break;
}
System.out.println("Snake eyes!");
```

## Two special loop keywords



- `break` - used to exit encapsulating loop immediately
- `continue` - used to skip to next iteration immediately
  - Use both with caution
  - Strive for legibility

```
// Handle numbers 1 to 10 except for 5
for (int i=0; i<10; i++) {
    if (i == 5) { // Guard code
        // Error handling code
        continue;
    }

    // Lots of lines of code
    ...
    ...
    ...
}
```

```
// Handle numbers 1 to 10 except for 5
for (int i=0; i<10; i++) {
    if (i != 5) {
        // Lots of lines of code
        ...
        ...
        ...
    }
    else {
        // Error handling code
    }
}
```

## *while* vs. *for* loops

---

**Fact.** Any *while* loop can be replaced with a *for* loop, and vice versa.

**Q.** Which one should I use?

**A.** Guiding principle: use loop construct that leads to clearer code.

**Rule-of-thumb.** Use *for* loops when you know the number of iterations ahead of time (Definite loops).

```
int i = 0;
while (i < n) {
    StdAudio.play(filename);
    i++;
}
```

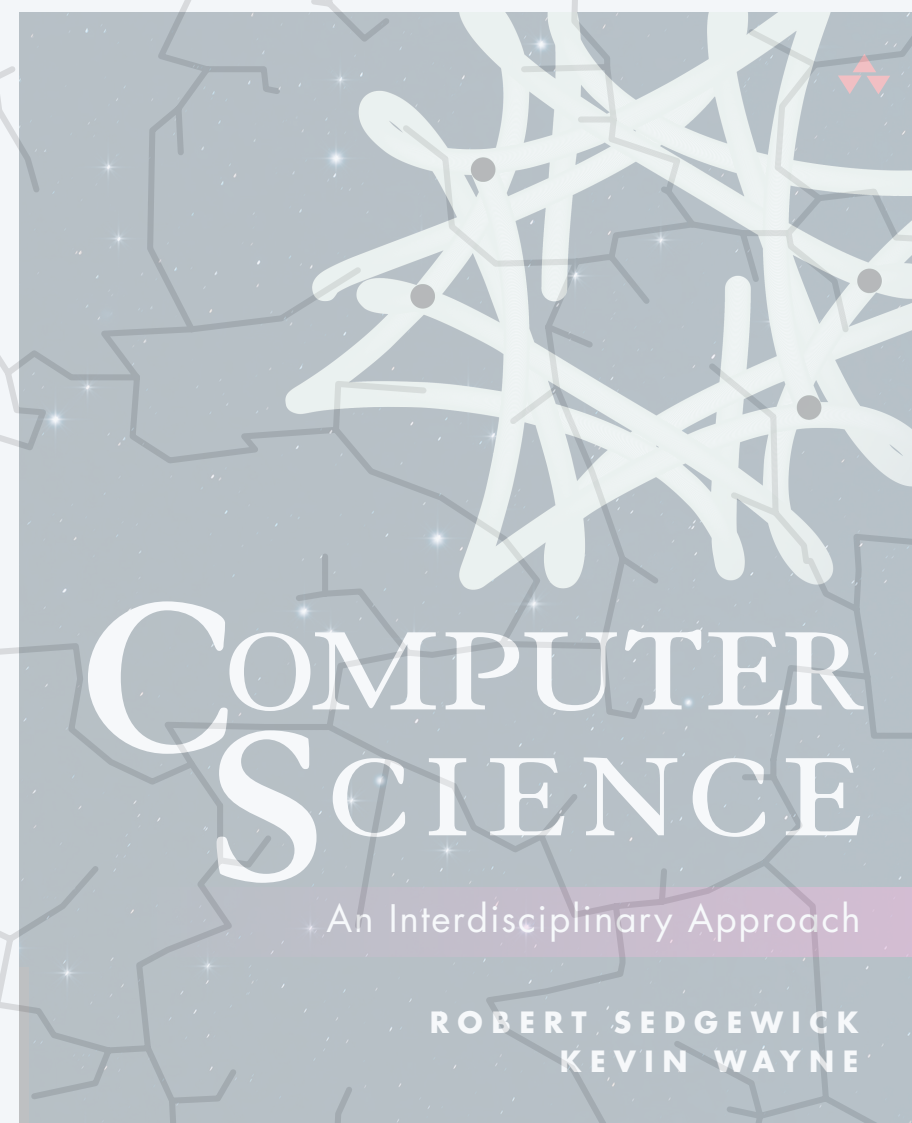
**while loop**

```
for (int i = 0; i < n; i++) {
    StdAudio.play(filename);
}
```

**equivalent for loop**  
(except *i* not accessible after loop)

*code controlling loop  
localized to one place*





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## LOOPS

---

- ▶ *while loops*
- ▶ *do-while loops*
- ▶ *for loops*
- ▶ *nested loops*
- ▶ *image processing*





- “A \_\_\_\_ within a \_\_\_\_\_”
- Nested loops – a loop within loop



- “A \_\_\_\_ within a \_\_\_\_\_”
- Nested loops – a loop within loop
- Printing every second in a minute



- “A \_\_\_\_ within a \_\_\_\_\_”
- Nested loops – a loop within loop
- Printing every second in a minute
- Pseudocode:

```
for (second = 0; second < 60; second++)  
    print(time)
```



- “A \_\_\_\_ within a \_\_\_\_\_”
- Nested loops – a loop within loop
- Printing every minute and second in an hour



- “A \_\_\_\_ within a \_\_\_\_\_”
- Nested loops – a loop within loop
- Printing every minute and second in an hour
- Pseudocode:

```
for (minute = 0; minute < 60; minute++)  
    for (second = 0; second < 60; second++)  
        print(time)
```



- “A \_\_\_\_ within a \_\_\_\_\_”
- Nested loops – a loop within loop
- It can get crazier
- Pseudocode:

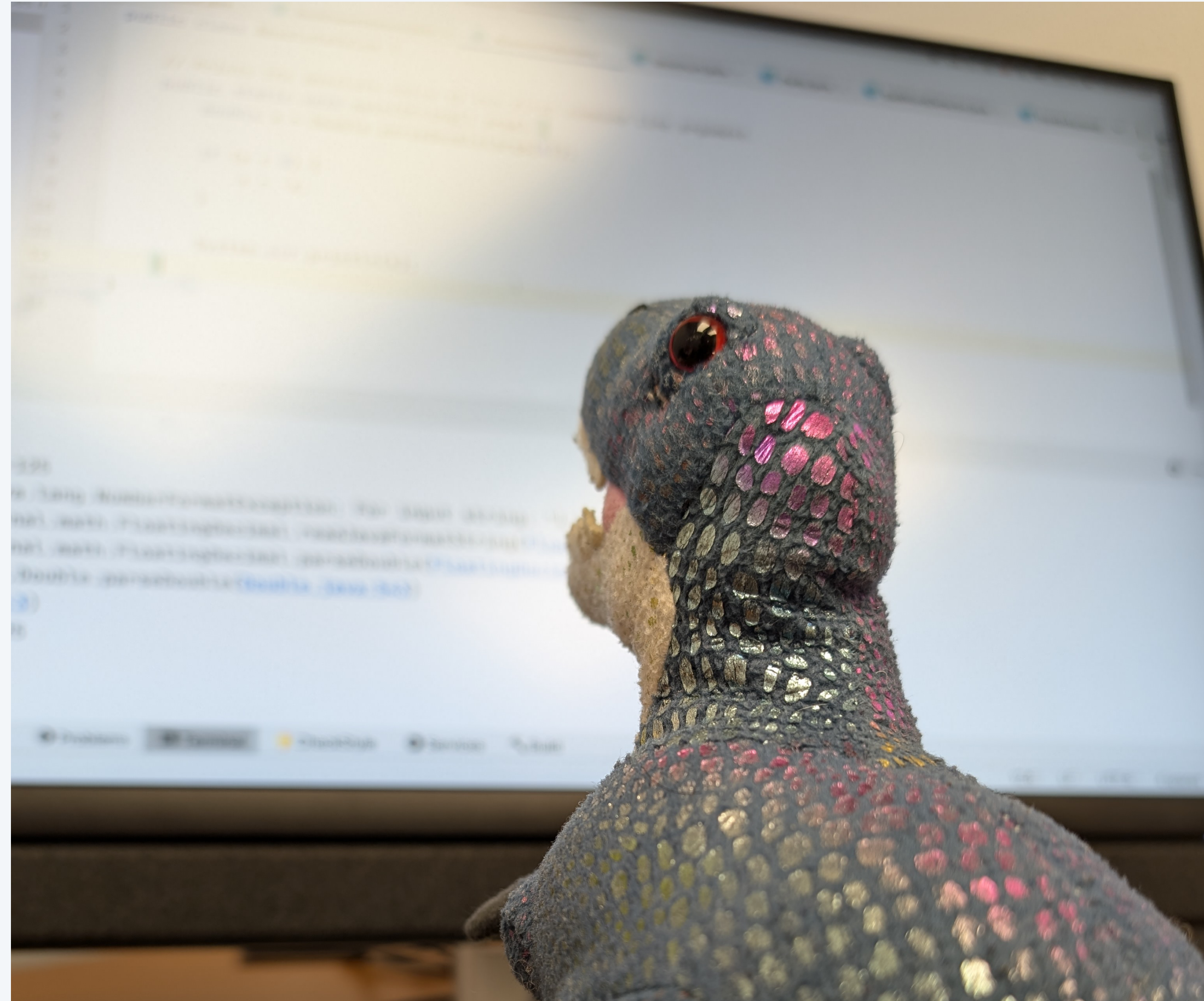
```
for (month = Jan; month <= December; month++)  
    for (day = 1; day < 31; day++) ← Need to handle exceptions  
        for (hour = 0; hour < 24; hour++)  
            for (minute = 0; minute < 60; minute++)  
                for (second = 0; second < 60; second++)  
                    print(time)
```

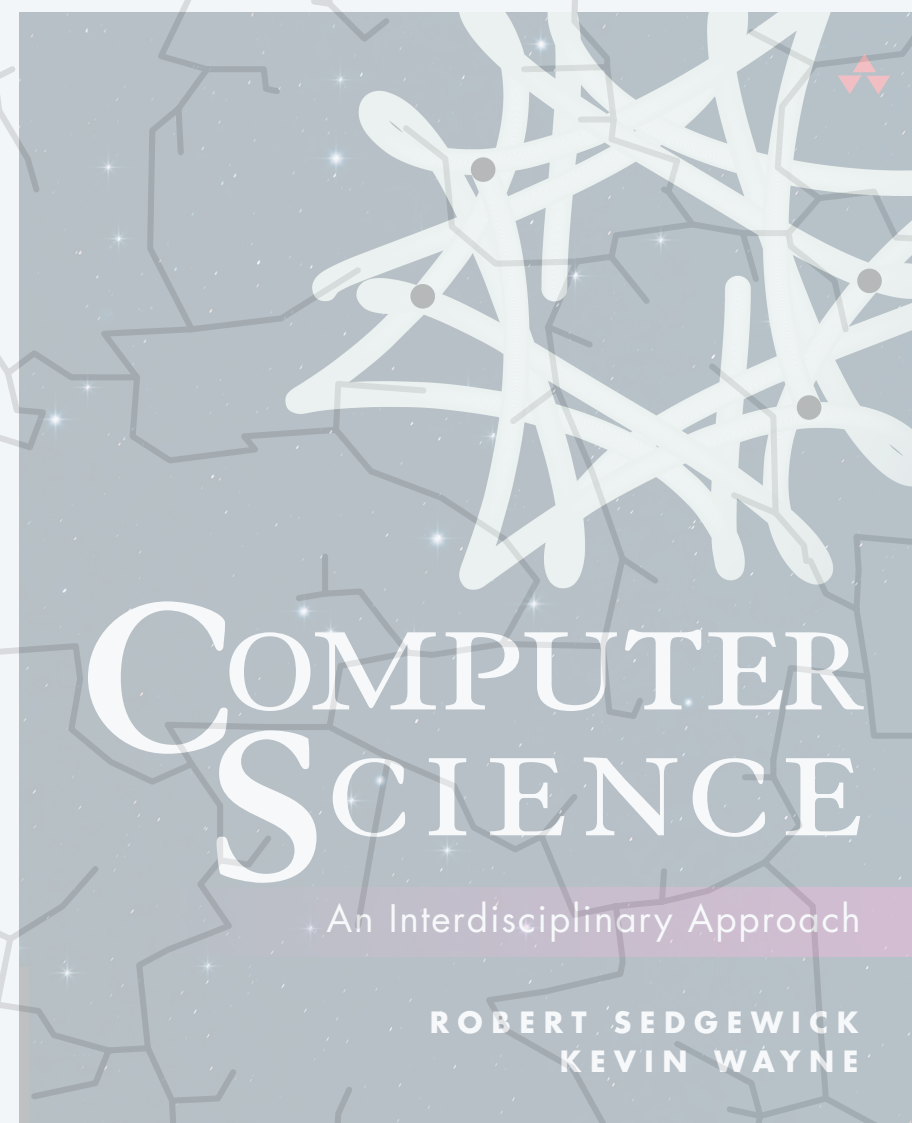


Suppose  $m = 4$  and  $n = 7$ . How many lines of output does the following program produce?

- A. 4
- B. 7
- C. 13
- D. 28
- E. 32

```
public class YetAnotherMystery {  
    public static void main(String[] args) {  
        int m = Integer.parseInt(args[0]);  
        int n = Integer.parseInt(args[1]);  
  
        for (int i = 0; i < m; i++) {  
            for (int j = 0; j < n; j++) {  
                System.out.println(i + ", " + j);  
            }  
        }  
    }  
}
```





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## LOOPS

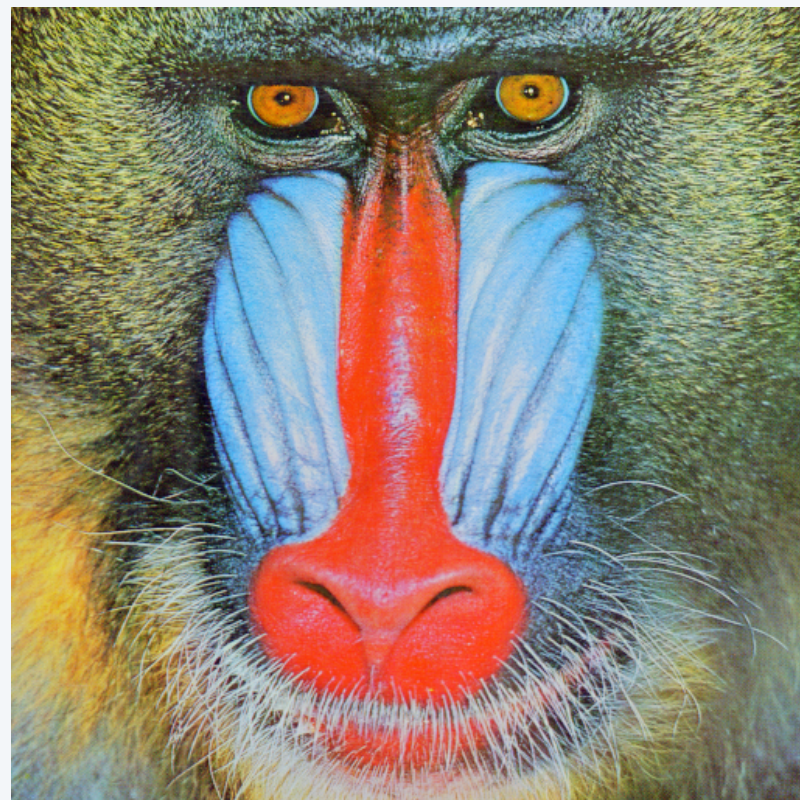
---

- ▶ *while loops*
- ▶ *do-while loops*
- ▶ *for loops*
- ▶ *nested loops*
- ▶ *image processing*



# Image processing

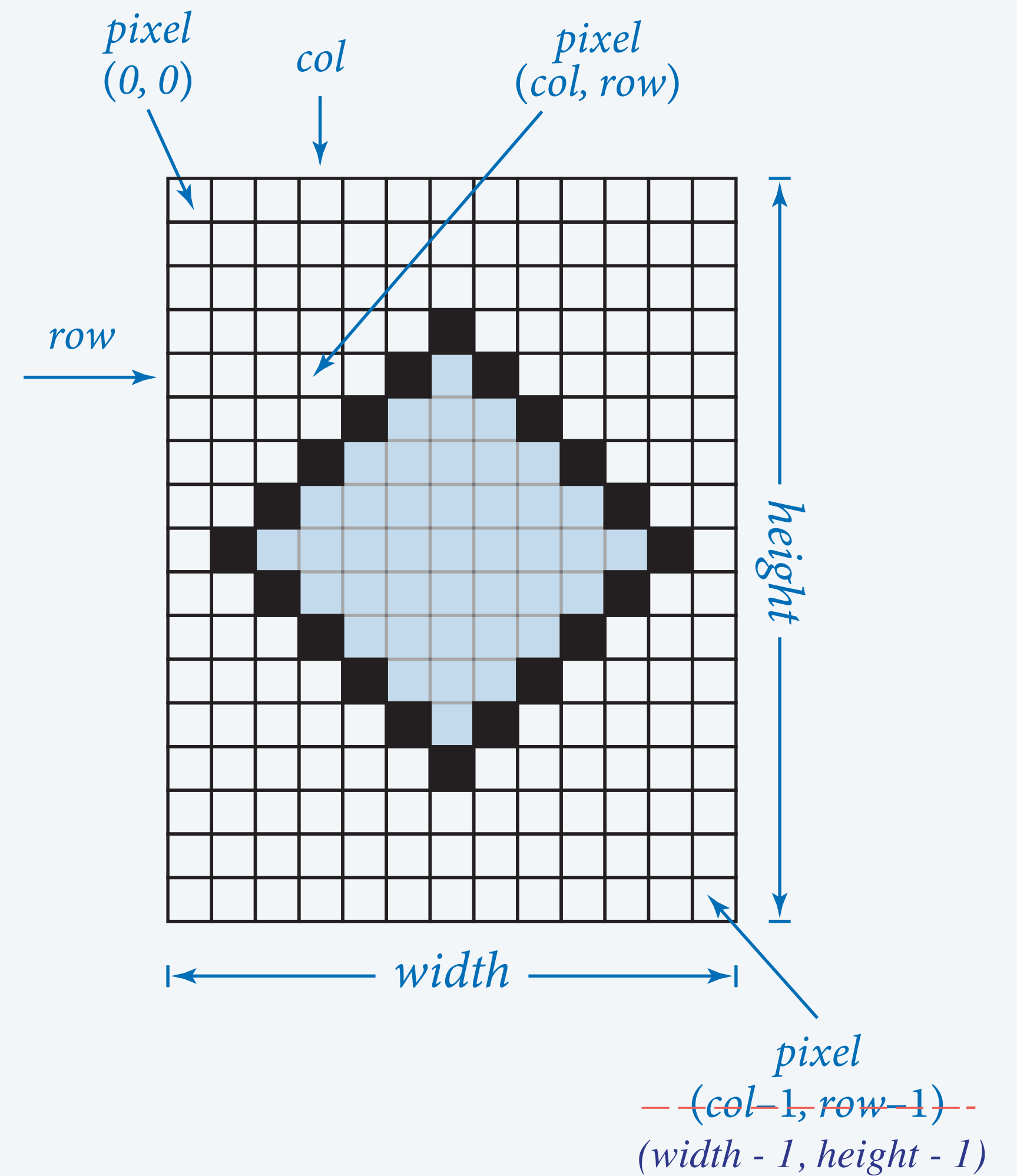
A **picture** is a *width-by-height* grid of pixels; each pixel has a **color**.



mandrill.jpg



arch.jpg



## Image-processing conventions.

- Pixel  $(i, j)$  means column  $i$  and row  $j$ .
- Pixel  $(0, 0)$  is upper-left.

← warning: different conventions from matrices, Cartesian coordinates, 2D arrays

# RGB color model


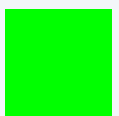


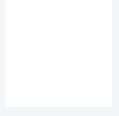

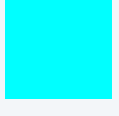

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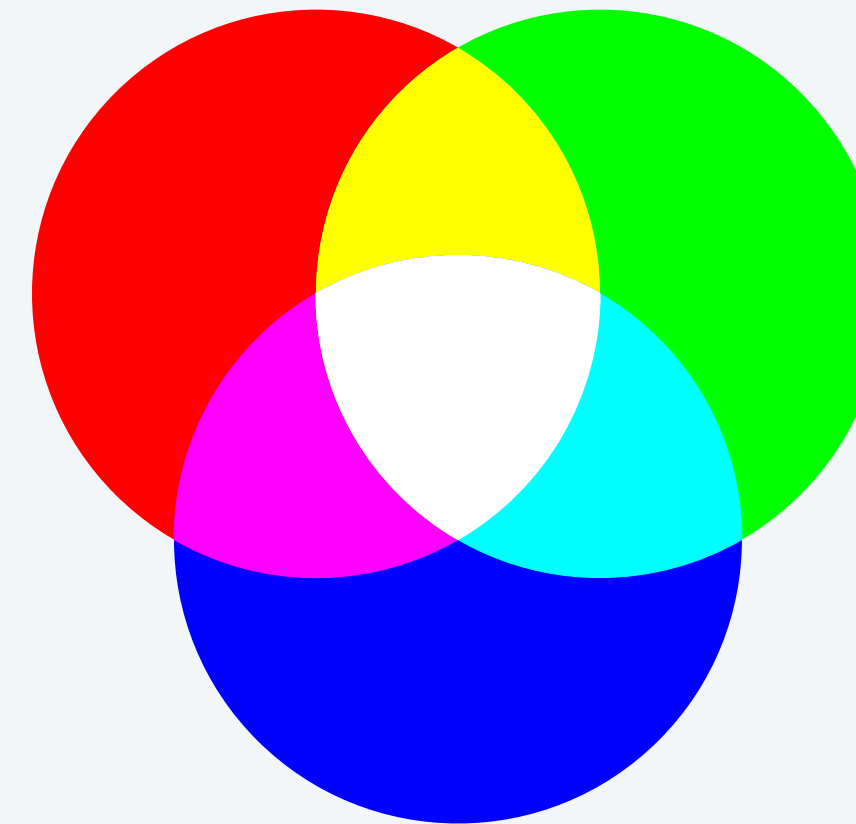
**Color** is a sensation in the eye from electromagnetic radiation.

**RGB color model.** Popular format for representing color on digital displays.

- Color is composed of red, green, and blue components.
- Each color component is an integer between 0 to 255.



<b>name</b>	<b>red</b>	<b>green</b>	<b>blue</b>	<b>color</b>
<i>red</i>	255	0	0	
<i>green</i>	0	255	0	
<i>blue</i>	0	0	255	
<i>black</i>	0	0	0	
<i>white</i>	255	255	255	
<i>yellow</i>	255	255	0	
<i>magenta</i>	255	0	255	
<i>cyan</i>	0	255	255	
<i>book blue</i>	0	64	128	



# Grayscale



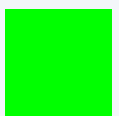
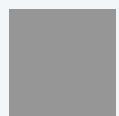




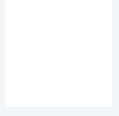
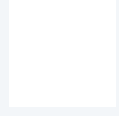
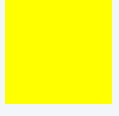
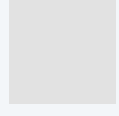

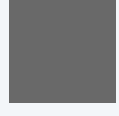
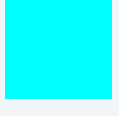
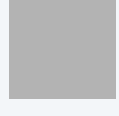


**Goal.** Convert color image to grayscale.

*fundamental operation  
in computer graphics and vision*

- RGB color is a shade of gray when  $R = G = B$ .
- To convert RGB color to grayscale, use **luminance** for  $R$ ,  $G$ , and  $B$  values:

*not the same as in ColorContrast!*  $\longrightarrow$   $Y = 0.299 R + 0.587 G + 0.114 B$



name	red	green	blue	color	lum	gray
<i>red</i>	255	0	0		76	
<i>green</i>	0	255	0		150	
<i>blue</i>	0	0	255		29	
<i>black</i>	0	0	0		0	
<i>white</i>	255	255	255		255	
<i>yellow</i>	255	255	0		226	
<i>magenta</i>	255	0	255		105	
<i>cyan</i>	0	255	255		179	
<i>book blue</i>	0	64	128		52	

$$\begin{aligned}
 Y &= 0.299 R + 0.587 G + 0.114 B \\
 &= 0.299 (0) + 0.587 (64) + 0.114 (128) \\
 &= 52.16
 \end{aligned}$$

# Standard picture library

*StdPicture*. Our library for manipulating images.

← *available with javac-introcs  
and java-introcs commands*

---

```
public class StdPicture
```

```
static void read(String filename)
```

*initialize picture from filename*

```
static void save(String filename)
```

*save picture to filename*

← *supported file formats:  
JPEG, PNG, GIF, TIFF, BMP*

```
static int width()
```

*width of picture*

```
static int height()
```

*height of picture*

```
static int getRed(int col, int row)
```

*red component of pixel (col, row)*

```
static int getGreen(int col, int row)
```

*green component of pixel (col, row)*

```
static int getBlue(int col, int row)
```

*blue component of pixel (col, row)*

```
static void setRGB(int col, int row,  
                  int r, int g, int b)
```

*set color of pixel (col, row) to (r, g, b)*

```
⋮
```

```
⋮
```

# Image processing: color image filters

---



**original**



**grayscale**



**sepia**



**duotone**



**brighter**



**darker**



**RGB layers**



**negative**

# Grayscale filter

```
public class Grayscale {
    public static void main(String[] args) {
        String filename = args[0];
        StdPicture.read(filename);
        int width = StdPicture.width();
        int height = StdPicture.height();

        for (int col = 0; col < width; col++) {
            for (int row = 0; row < height; row++) {
                int r = StdPicture.getRed(col, row);
                int g = StdPicture.getGreen(col, row);
                int b = StdPicture.getBlue(col, row);
                int y = (int) (Math.round(0.299*r + 0.587*g + 0.114*b));
                StdPicture.setRGB(col, row, y, y, y);
            }
        }

        StdPicture.show();
    }
}
```

*read picture from file and get dimensions*

*iterate over all pixels*

*get RGB values*

*luminance formula*  
( $Y = 0.299R + 0.587G + 0.114B$ )

*display picture in window*



# Compute the negative: demo



**Goal.** Find the negative of an image (where light colors become dark and vice-versa).

**Algorithm.** For each pixel with color values  $(r, g, b)$ , replace it with  $(255 - r, 255 - g, 255 - b)$ .

(0, 0)	(1, 0)	(2, 0)	(3, 0)	(4, 0)	(5, 0)
(0, 1)	(1, 1)	(2, 1)	(3, 1)	(4, 1)	(5, 1)
(0, 2)	(1, 2)	(2, 2)	(3, 2)	(4, 2)	(5, 2)
(0, 3)	(1, 3)	(2, 3)	(3, 3)	(4, 3)	(5, 3)

original image

(0, 0)	(1, 0)	(2, 0)	(3, 0)	(4, 0)	(5, 0)
(0, 1)	(1, 1)	(2, 1)	(3, 1)	(4, 1)	(5, 1)
(0, 2)	(1, 2)	(2, 2)	(3, 2)	(4, 2)	(5, 2)
(0, 3)	(1, 3)	(2, 3)	(3, 3)	(4, 3)	(5, 3)

negative image

## Compute the negative: implementation

---

**Goal.** Find the negative of an image (where light colors become dark and vice-versa).

**Algorithm.** For each pixel with color values  $(r, g, b)$ , replace it with  $(255 - r, 255 - g, 255 - b)$ .

```
for (int row = 0; row < height; row++) {
    for (int col = 0; col < width; col++) {
        int r = StdPicture.getRed(col, row);
        int g = StdPicture.getGreen(col, row);
        int b = StdPicture.getBlue(col, row);

        StdPicture.setRGB(col, row, 255 - r, 255 - g, 255 - b);
    }
}
```

~/> java-introcs Negative MyImage.jpg





What image does the following code fragment produce?

- A. Original image.
- B. Negative.
- C. Red channel.
- D. Blue channel.
- E. Green channel.



```
for (int col = 0; col < width; col++) {  
    for (int row = 0; row < height; row++) {  
        int r = StdPicture.getRed(col, row);  
        int g = StdPicture.getGreen(col, row);  
        int b = StdPicture.getBlue(col, row);  
  
        StdPicture.setRGB(col, row, r, 0, 0);  
    }  
}
```

← *for loops in reverse*

← *different arguments to setRGB*

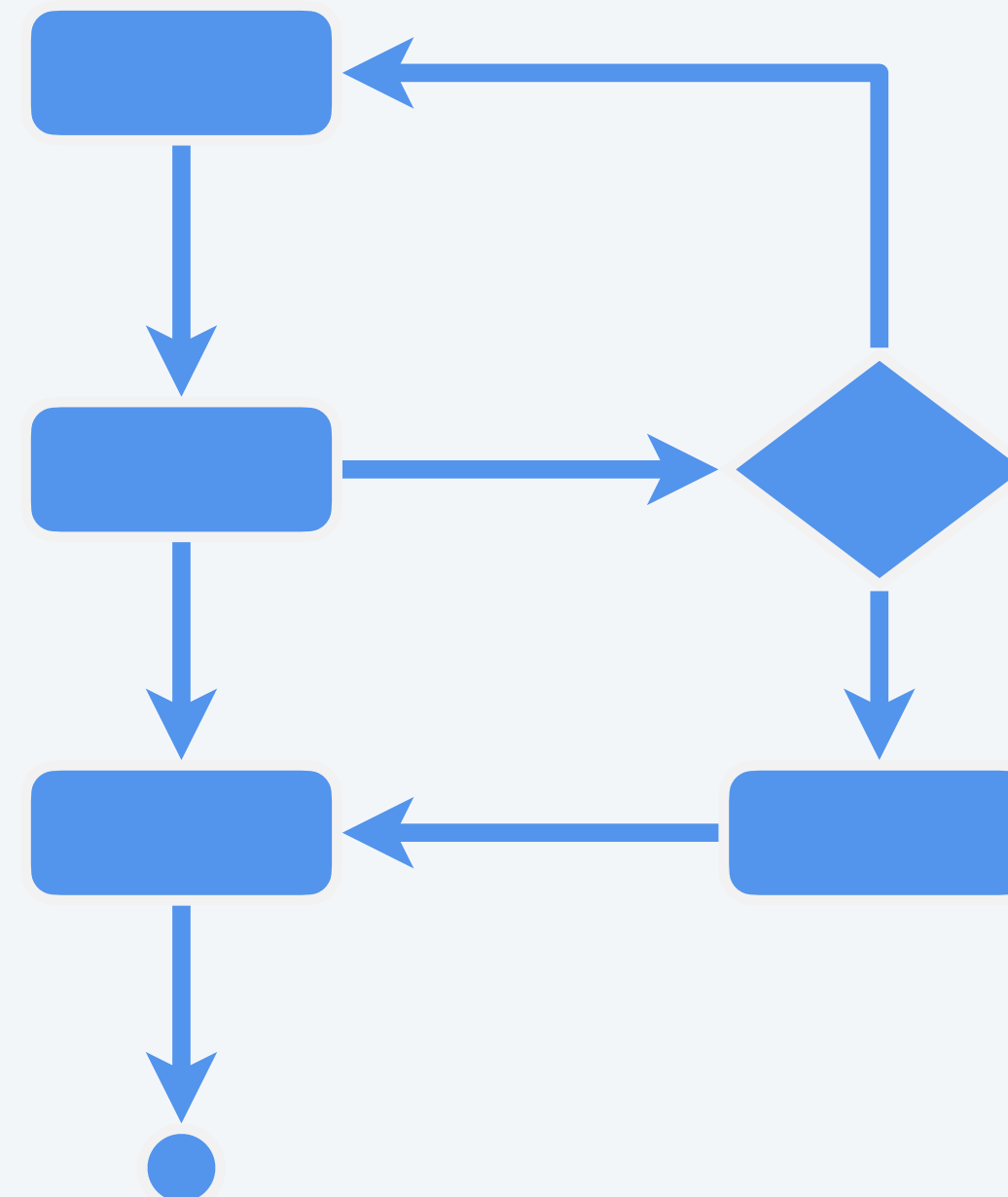
# Summary

---

**Iteration.** Use *while* and *for* loops to repeat code in a program.

**Nested iteration.** Body of loop contains another loop.

**Image processing.** An image is a 2D grid of pixels, each of which has r, g and b color levels.



control flow with conditionals and loops

# Credits

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<i>Image Processing Icon</i>	<u>Adobe Stock</u>	<u>education license</u>
<i>Mandrill</i>	<u>USC SIPI Image Database</u>	
<i>Johnson Arch</i>	<u>Danielle Alio Capparella</u>	by photographer
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