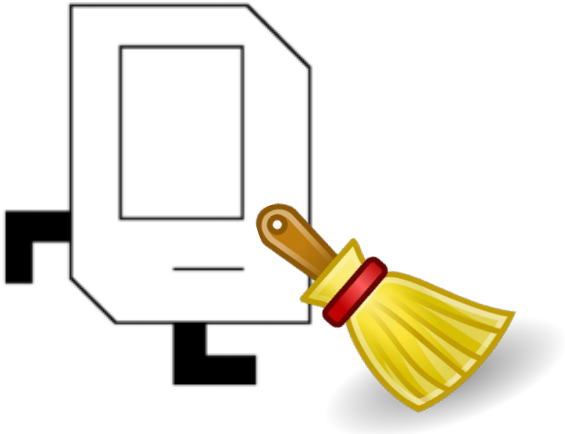
# Control Flow

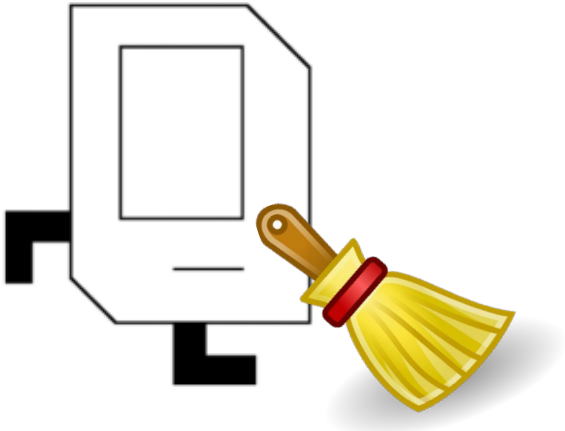
Chris Gregg and Mehran Sahami
CS106A, Stanford University

# Housekeeping I



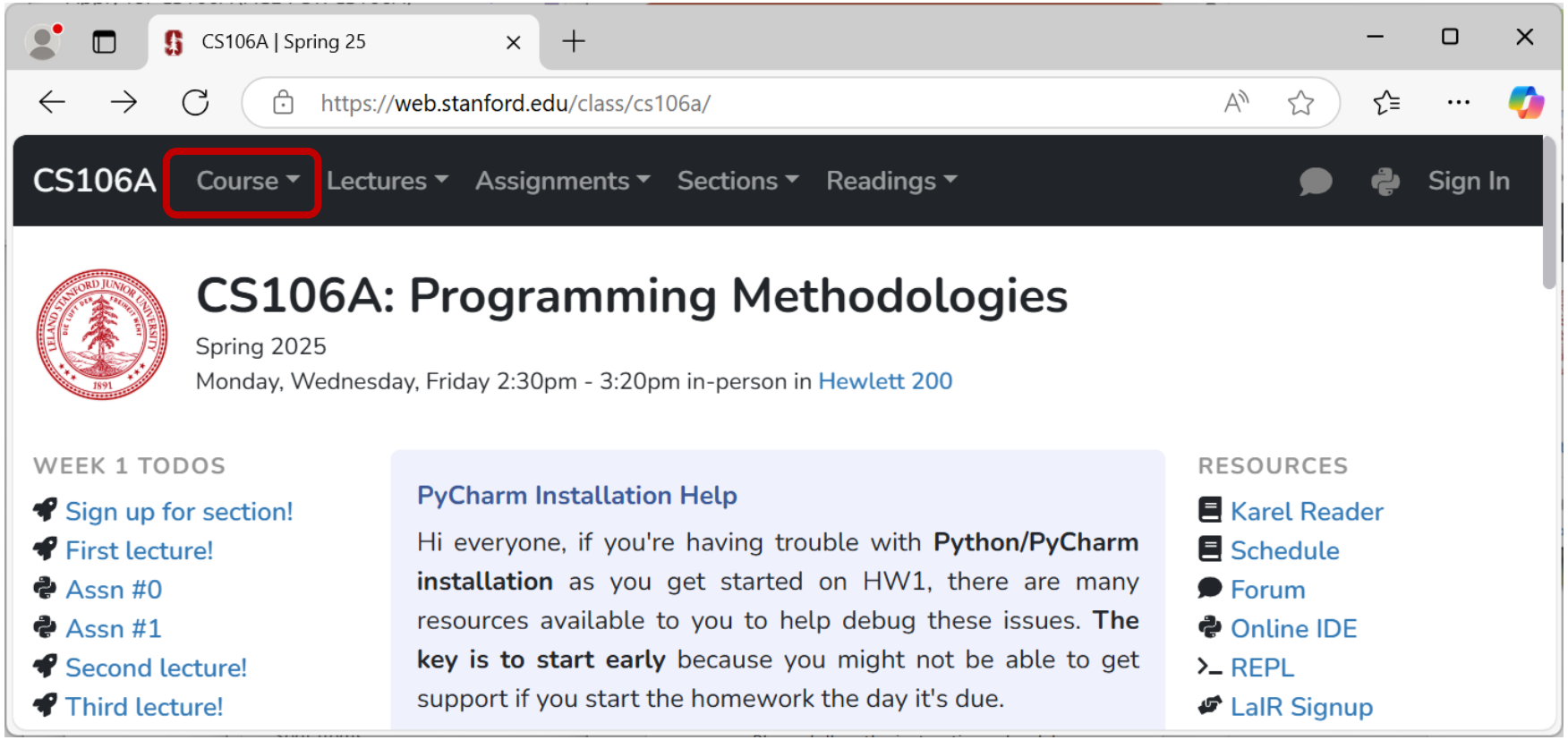
- Class website: http://cs106a.stanford.edu
- Section sign-ups (sections start next week)
  - Sign-up at: http://cs198.stanford.edu (will be on CS106A page)
  - Sign-ups start Thurs., Apr. 3 at 5pm; end Sun., Apr. 6 at 5pm
- Assignment #0 still open (over 150 responses already)
  - About 65% taking class for "Fun and Enlightenment"
  - About 65% have 0-10 hours coding experience
- Assignment #1 released, due April 11 at 11:59pm

# Housekeeping II

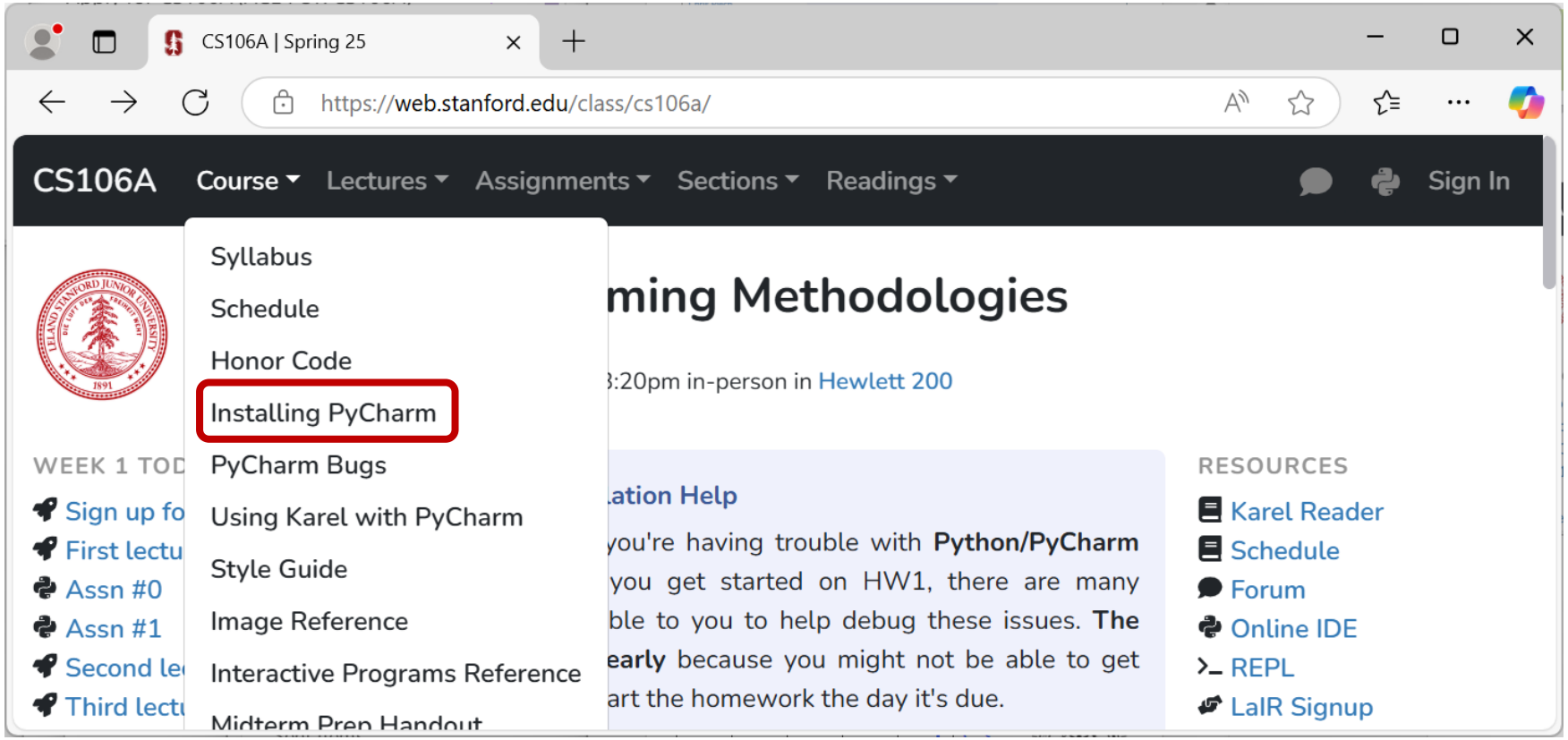


- Please send OAE letters to Ngoc (Head TA)
- Application open for CS100A (link on CS106A Ed **Forum**)
  - 1-unit supplementary section for stronger foundation
- "Forum" for questions/discussion
  - Link on top right corner of CS106A class web page
- LaIR Helper Hours start this Sunday (April 6)
  - Located in Durand Building, 3rd floor

# Install PyCharm



# Install PyCharm

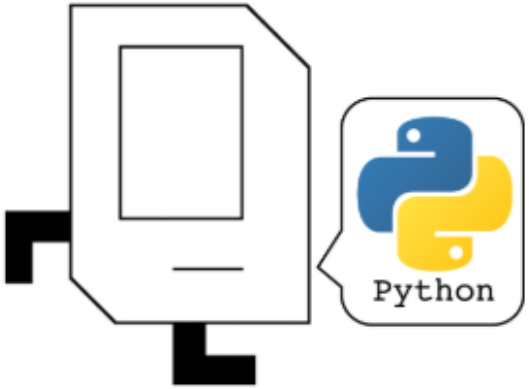



Please follow the instructions *closely*!

PyCharm installation help session on

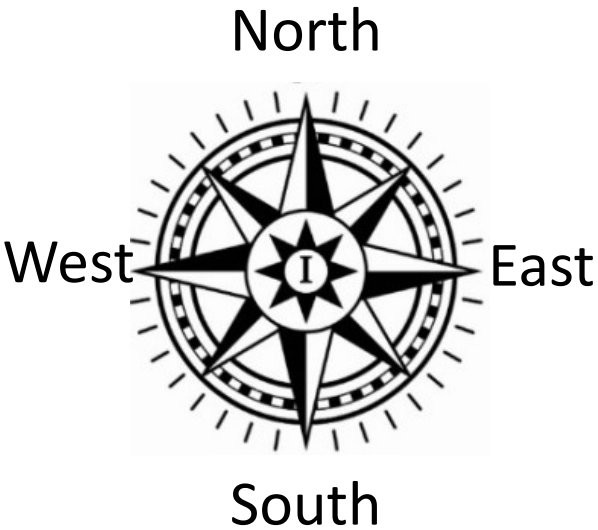
Thursday, April 3, 7-8:30pm in CoDa B45

# Using Karel and Assignment 1




- Reading: Should read the “Karel Reader” on class website
  - Link on top right corner of CS106A webpage
- Handout: “Honor Code”
- Handout: “Using Karel with PyCharm”
  - Tells you how to get started with writing Karel programs
- Handout: “Assignment 1”
  - Set of Karel programs for you to write
  - Due 11:59pm on Friday, April 11th
- Only use features of Karel in the course reader
  - No other features of Python may be used in Karel programs!

# Recall, Karel's World

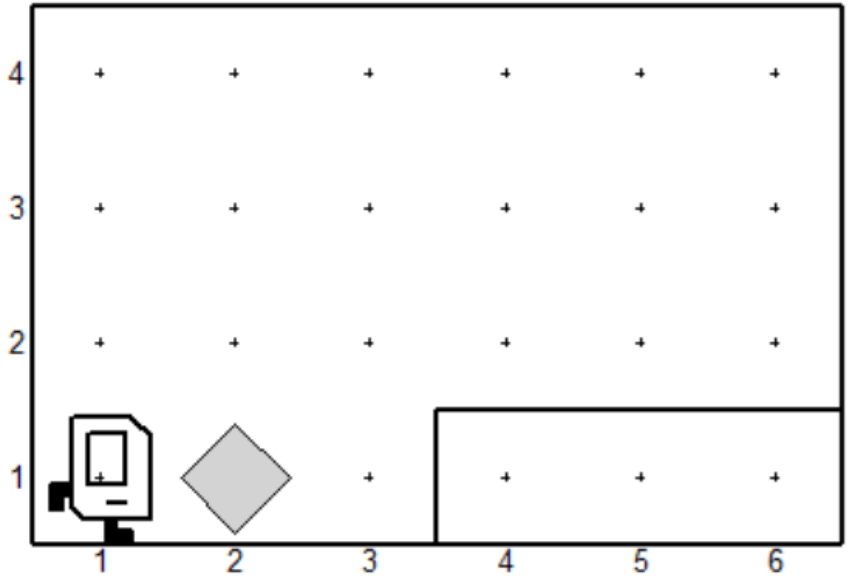




- Grid, where "corner" is intersection of each street/avenue
- Karel is currently on corner (1, 1)
- If Karel moved forward, Karel would be on corner (2, 1)
- Karel's beeper bag can have 0, 1, or more (up to infinite) beepers

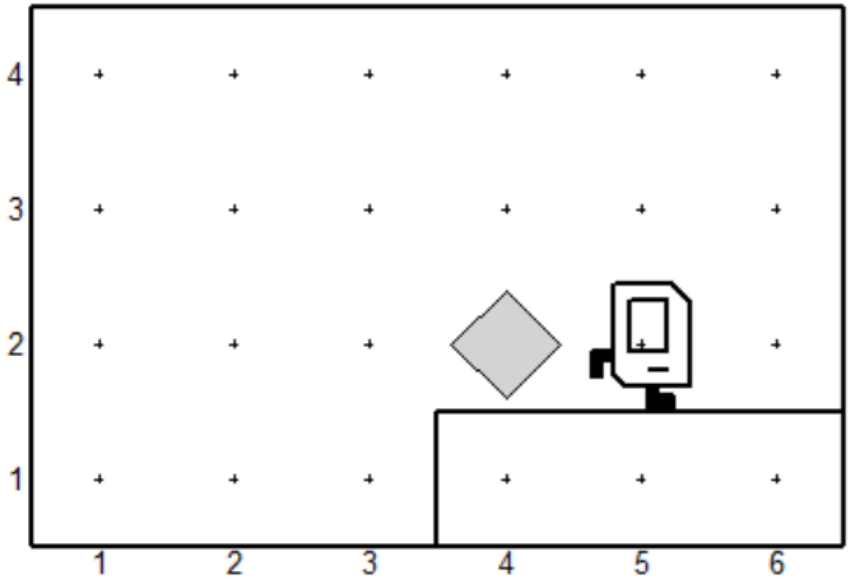
# Recall: Step-Up Example

https://ide.stanford.edu/cs106a/a/stepup

Starting world:




Ending world:



# Anatomy of a Program

Import Packages

Program

# Anatomy of a Program

Import Packages

main function

helper functions

start program

# Anatomy of a Program

Import Packages

```
def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()
```

helper functions

start program

# Anatomy of a Program

Import Packages

```
def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()
```

helper functions

start program

# Function Definition

```
def name():
    function statements
```

This adds a new command to Karel's vocabulary

# Anatomy of a Program

```
Import Packages
```

```
def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()

def turn_right():
    turn_left()
    turn_left()
    turn_left()
```

```
start program
```

# Anatomy of a Program

```
Import Packages
```

```
def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()

def turn_right():
    turn_left()
    turn_left()
    turn_left()

if __name__ == "__main__":
     run_karel_program()
```

# Anatomy of a Program

```
from karel.stanfordkarel import *

def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()

def turn_right():
    turn_left()
    turn_left()
    turn_left()

if __name__ == "__main__":
    run_karel_program()
```

# Anatomy of a Program

```
from karel.stanfordkarel import *

def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()

def turn_right():
    turn_left()
    turn_left()
    turn_left()

if __name__ == "__main__":
    run_karel_program()
```

# Anatomy of a Program

```
from karel.stanfordkarel import *

def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()

def turn_right():
    turn_left()
    turn_left()
    turn_left()

if __name__ == "__main__":
    run_karel_program()
```

This piece of the program's ***source code*** is called a ***function***.

# Anatomy of a Program

```
from karel.stanfordkarel import *

def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
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    move()

def turn_right():
    turn_left()
    turn_left()
    turn_left()

if __name__ == "__main__":
    run_karel_program()
```

This line of code gives the ***name*** of the function (here, the name is: **`main`**)

# Anatomy of a Program

```
from karel.stanfordkarel import *

def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()

def turn_right():
    turn_left()
    turn_left()
    turn_left()

if __name__ == "__main__":
    run_karel_program()
```

This line of code gives the ***name*** of the function
(here, the name is: **`turn_right`**)

# Anatomy of a Program

```
from karel.stanfordkarel import *

def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()

def turn_right():
    turn_left()
    turn_left()
    turn_left()

if __name__ == "__main__":
    run_karel_program()
```

This is called a ***code block***
(Note the indenting)

# Anatomy of a Program

```
from karel.stanfordkarel import *

def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()

def turn_right():
    turn_left()
    turn_left()
    turn_left()

if __name__ == "__main__":
    run_karel_program()
```

This is called a ***code block***
(Note the indenting)

# First Lesson in Programming Style

```
from karel.stanfordkarel import *

"""
File: StepUpKarel.py
--------------------
Karel program, where Karel picks up a beeper,
jumps up on a step and drops the beeper off.
"""

def main():
    move()
    pick_beeper()
    move()
    turn_left()
    move()
    turn_right()
    move()
    put_beeper()
    move()

# Karel turns to the right
def turn_right():
    turn_left()
    turn_left()
    turn_left()
```

Multi-line ***comment***

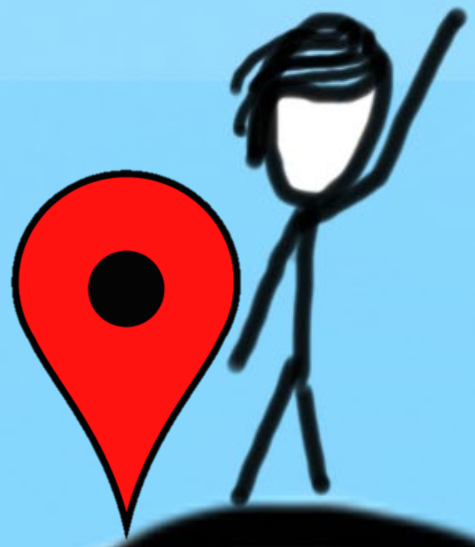
**SOFTWARE ENGINEERING PRINCIPLE**:
Aim to make programs readable by ***humans***

One line ***comment***

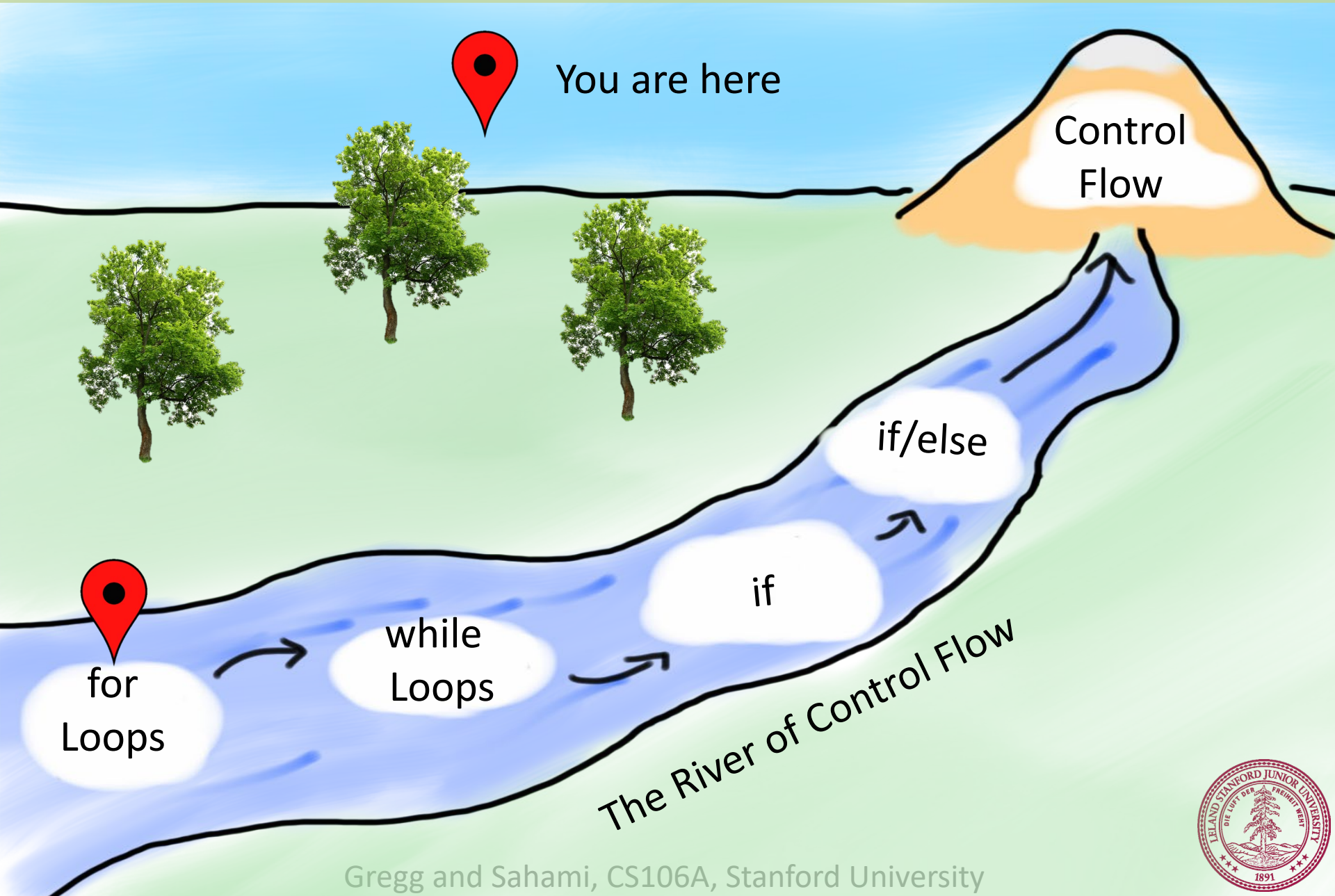
Descriptive ***names*** (snake_case)

# Today's Goal

1. Code using loops and conditions
2. Trace programs that use loops and conditions



# Today's Route



# for loop

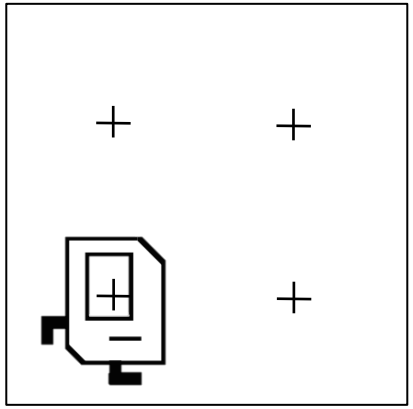
```
for i in range(count):
    statements                    # note indenting
```

---

```
def turn_right():
    for i in range(3):
        turn_left()    # note indenting
```

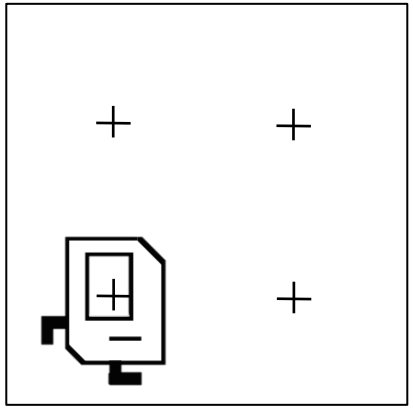
# Place Beeper Square

```
def main():
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```



# Place Beeper Square

```
def main():
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```



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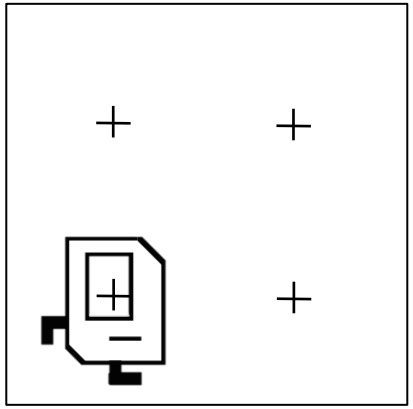

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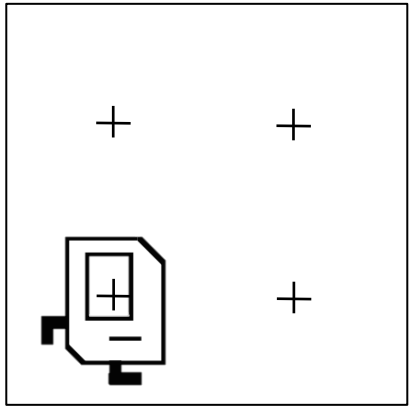
```



First time through the loop

# Place Beeper Square

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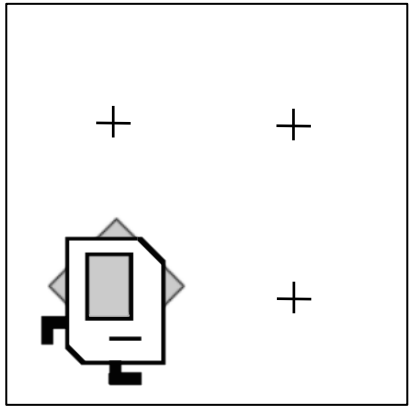
def main():
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```



First time through the loop

# Place Beeper Square

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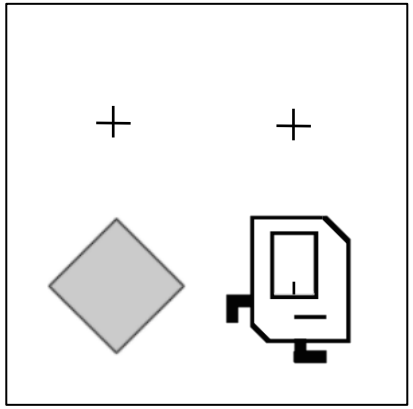

First time through the loop

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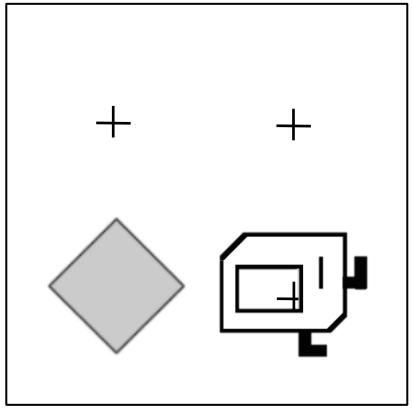
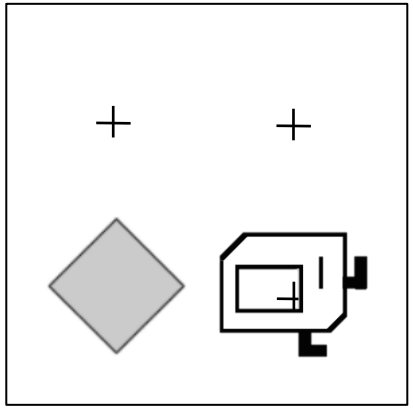
```



First time through the loop

# Place Beeper Square

```
def main():
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```



**Second** time through the loop

# Place Beeper Square

```
def main():
    for i in range(4):
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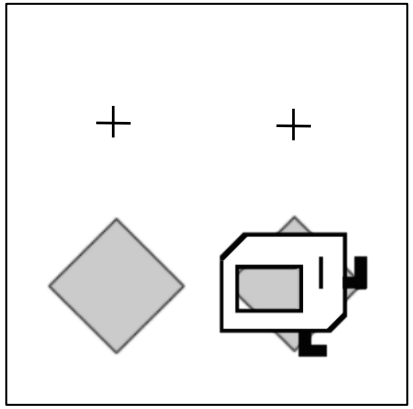
        move()
        turn_left()
```



**Second** time through the loop

# Place Beeper Square

```
def main():
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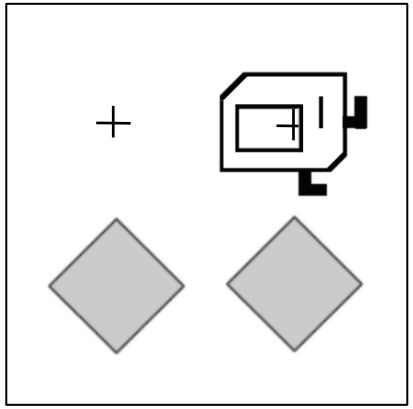
```



**Second** time through the loop

# Place Beeper Square

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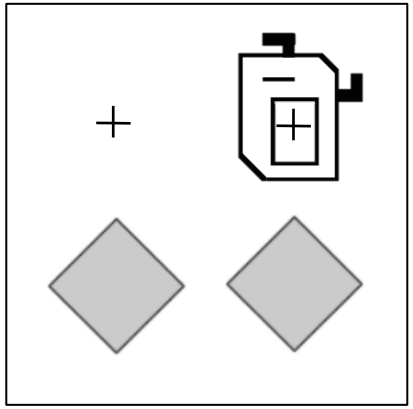
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```



**Second** time through the loop

# Place Beeper Square

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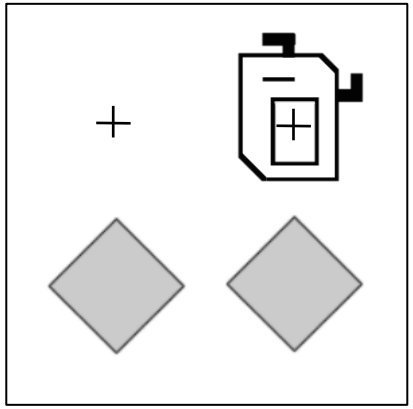
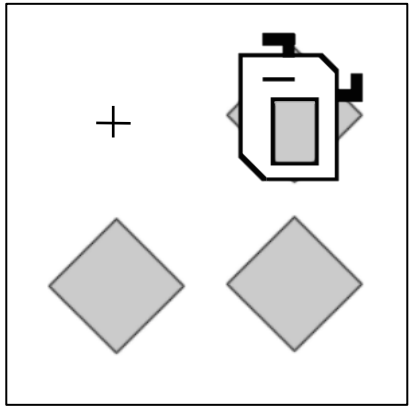
def main():
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```



**Third** time through the loop

# Place Beeper Square

```
def main():
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```



**Third** time through the loop

# Place Beeper Square

```
def main():
    for i in range(4):
        put_beeper()
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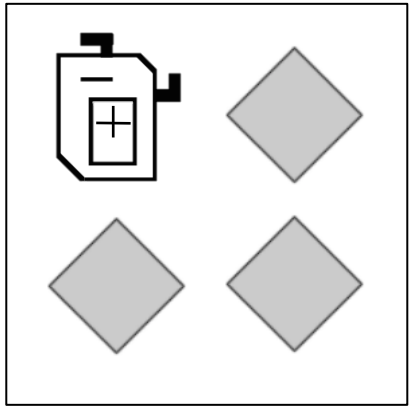
        turn_left()
```



**Third** time through the loop

# Place Beeper Square

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def main():
    for i in range(4):
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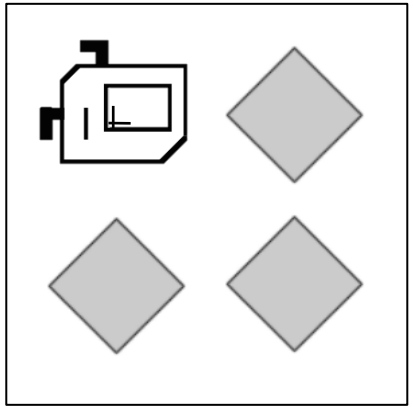

**Third** time through the loop

# Place Beeper Square

```
def main():
    for i in range(4):
        put_beeper()
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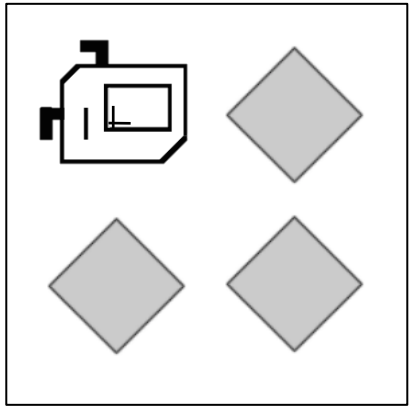
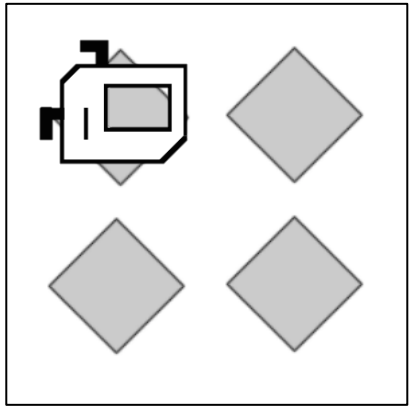
```



**Fourth** time through the loop

# Place Beeper Square

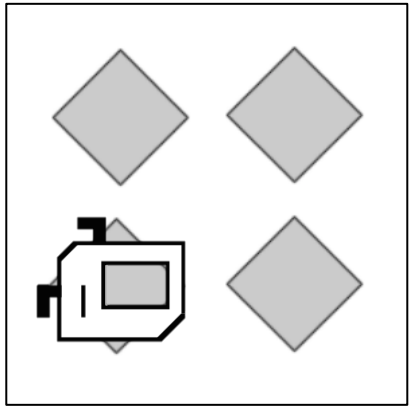
```
def main():
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```



**Fourth** time through the loop

# Place Beeper Square

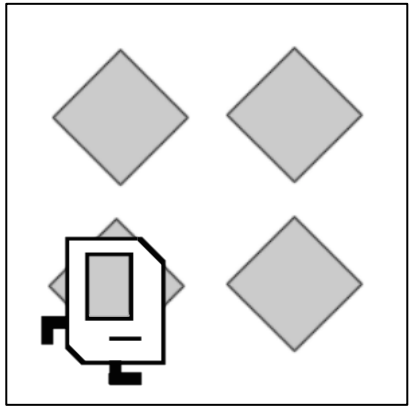
```
def main():
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```



**Fourth** time through the loop

# Place Beeper Square

```
def main():
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```

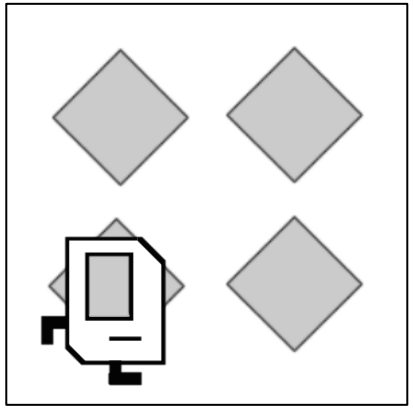


**Fourth** time through the loop

# Place Beeper Square

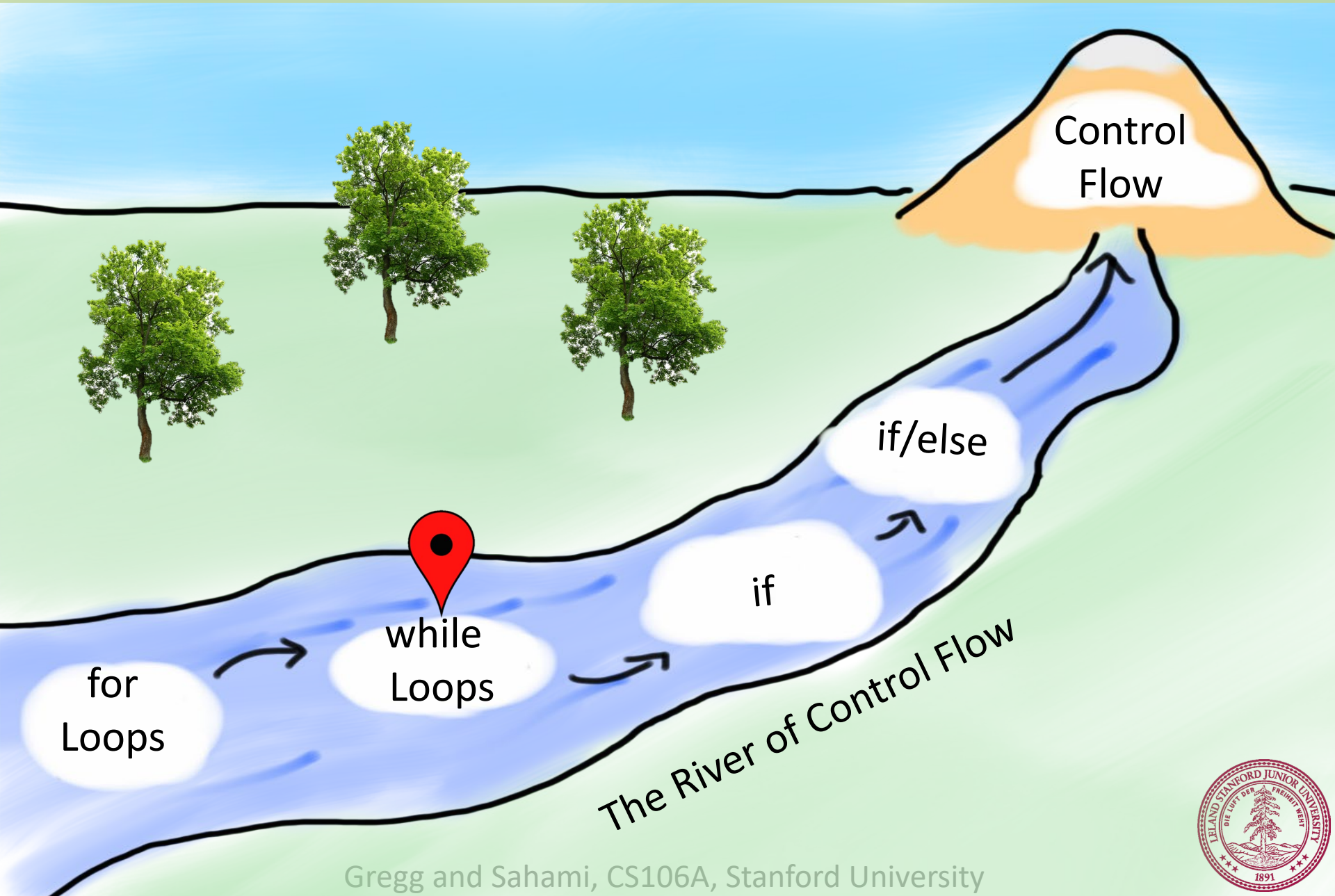
```
def main():
    for i in range(4):
        put_beeper()
        move()
        turn_left()
```

You often want the **postcondition** of a loop to match the **precondition**



Done!

# Today's Route



# `while` loop

```
while condition:
    statements                    # note indenting
```

---

```
def move_to_wall():
    while front_is_clear():
        move()                    # note indenting
```

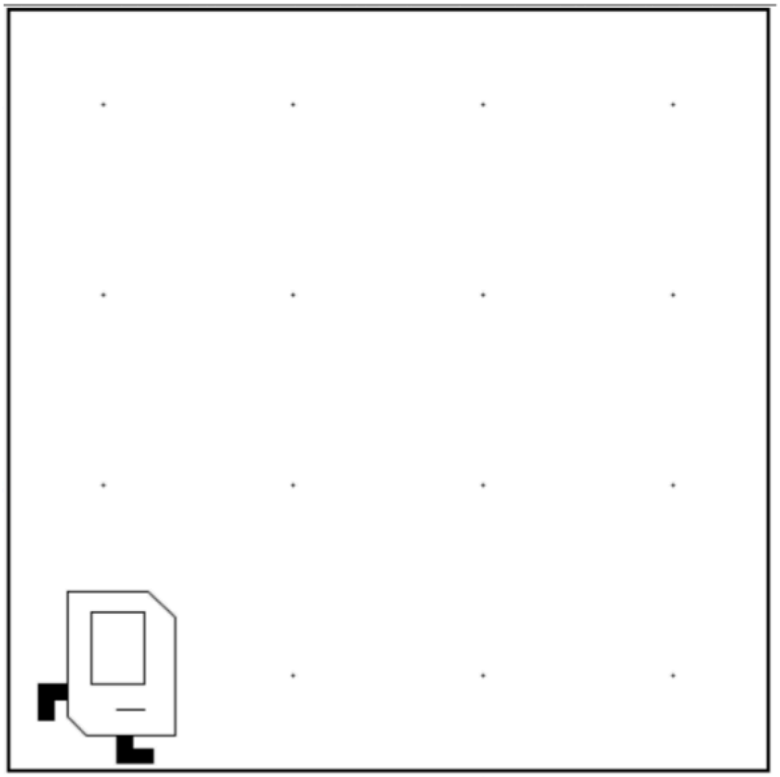
# Conditions Karel Can Check For

| *Test* | *Opposite* | *What it checks* |
|---|---|---|
| `front_is_clear()` | `front_is_blocked()` | Is there a wall in front of Karel? |
| `left_is_clear()` | `left_is_blocked()` | Is there a wall to Karel's left? |
| `right_is_clear()` | `right_is_blocked()` | Is there a wall to Karel's right? |
| `beepers_present()` | `no_beepers_present()` | Are there beepers on this corner? |
| `beepers_in_bag()` | `no_beepers_in_bag()` | Any there beepers in Karel's bag? |
| `facing_north()` | `not_facing_north()` | Is Karel facing north? |
| `facing_east()` | `not_facing_east()` | Is Karel facing east? |
| `facing_south()` | `not_facing_south()` | Is Karel facing south? |
| `facing_west()` | `not_facing_west()` | Is Karel facing west? |

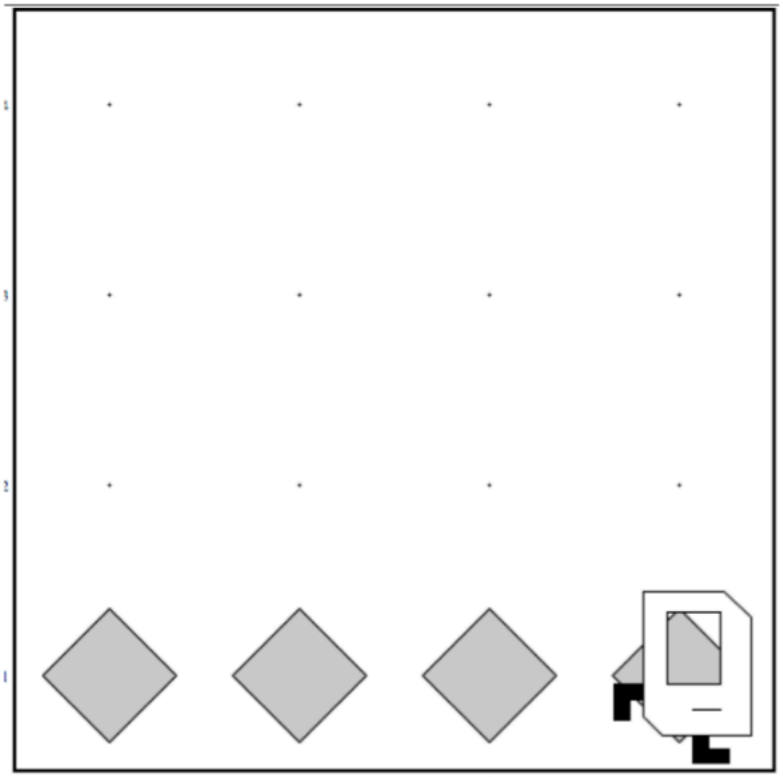
This is in Chapter 10 of the online Karel course reader

# Task: Place Beeper Line

Before



After



# Place Beeper Line

```
def main():
    while front_is_clear():
        put_beeper()
        move()
```

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def main():
    while front_is_clear():
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        move()
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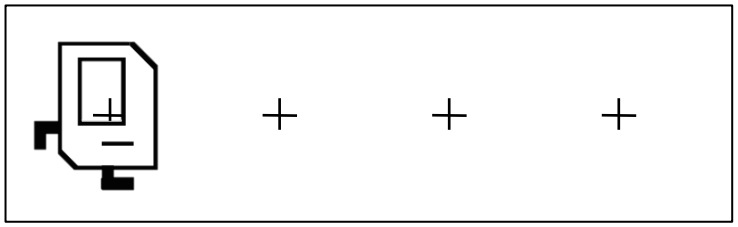

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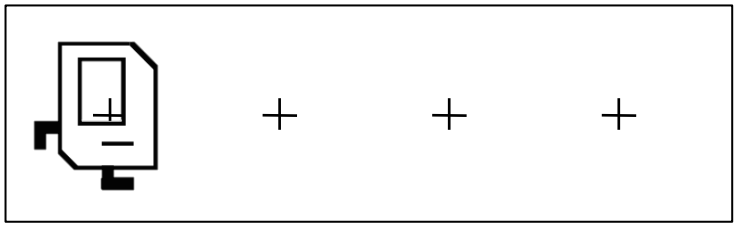

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def main():
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        move()
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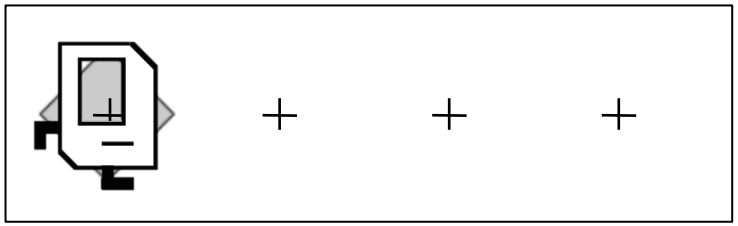

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    while front_is_clear():
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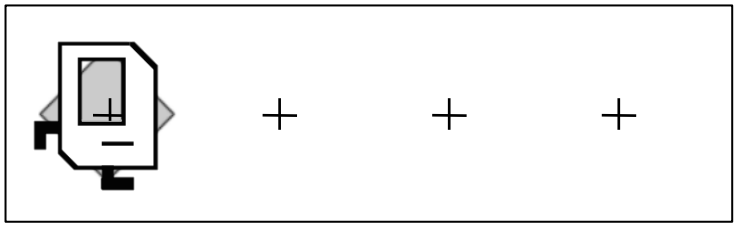

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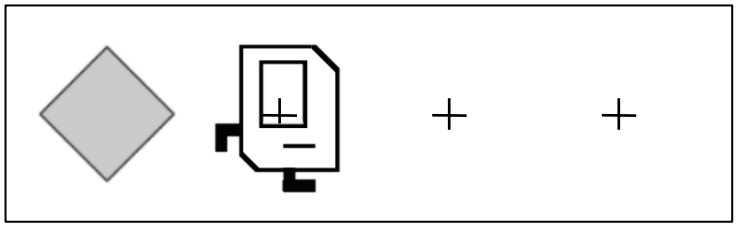
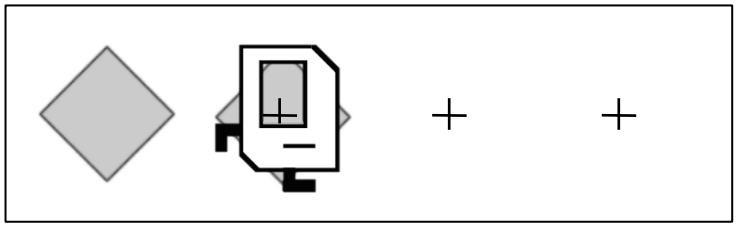


# Place Beeper Line

```
def main():
    while front_is_clear():
        put_beeper()
        move()
```



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```
def main():
    while front_is_clear():
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        move()
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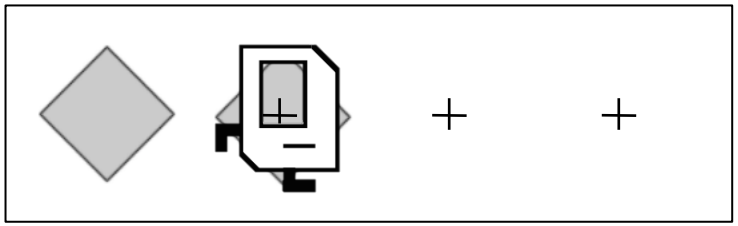

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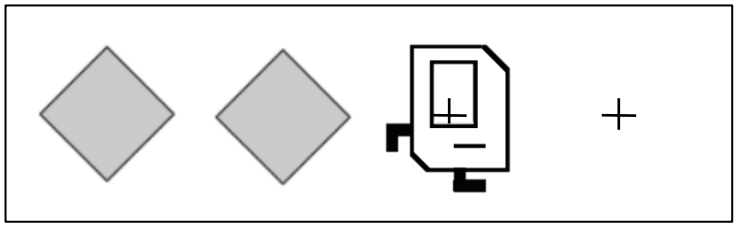

# Place Beeper Line

```
def main():
    while front_is_clear():
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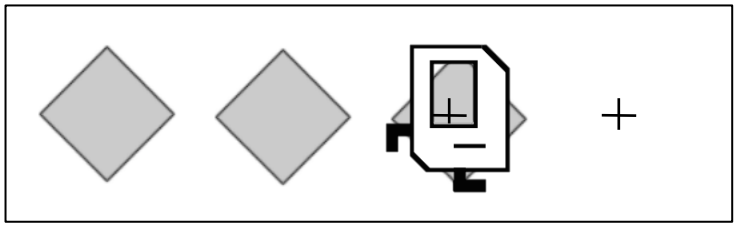
        move()
```



# Place Beeper Line

```
def main():
    while front_is_clear():
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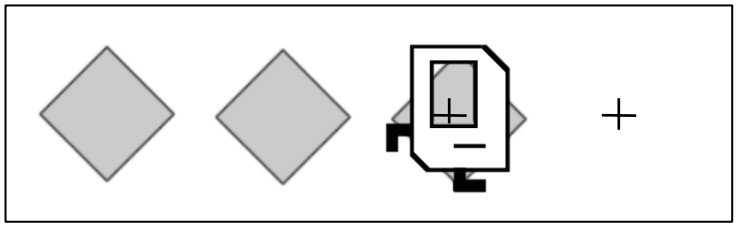
        move()
```



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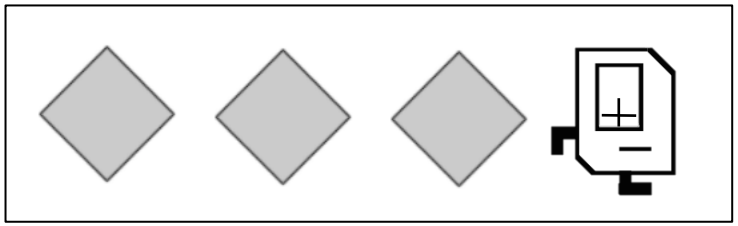
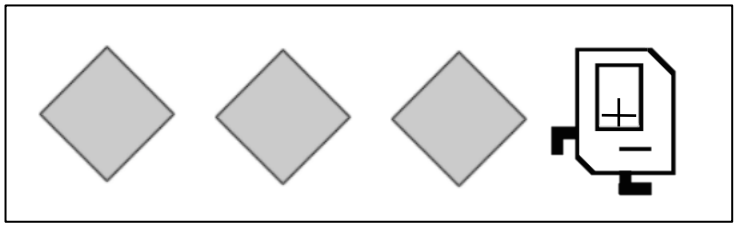


# Place Beeper Line

```
def main():
    while front_is_clear():
        put_beeper()
        move()
```

**BUGGY!**

**Done!**

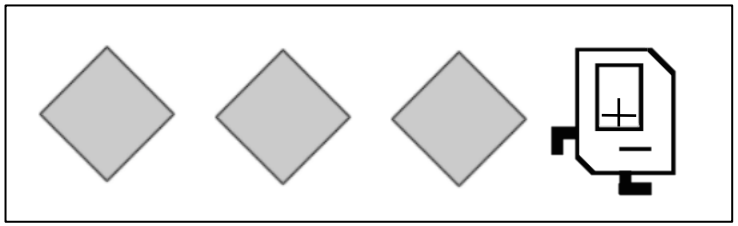


# Place Beeper Line

```
def main():
    while front_is_clear():
        put_beeper()
        move()
    put_beeper()          # add final put_beeper
```

Not in **while** loop

Fixed!



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```
def main():
    while front_is_clear():
        put_beeper()
        move()
    put_beeper()        # add final put_beeper
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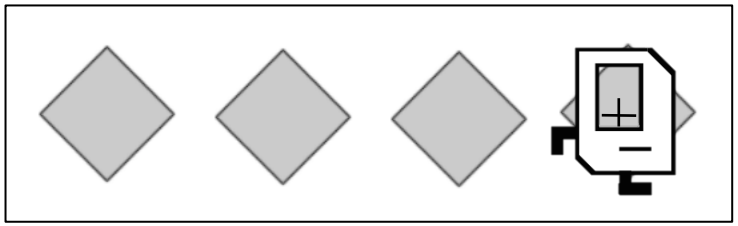
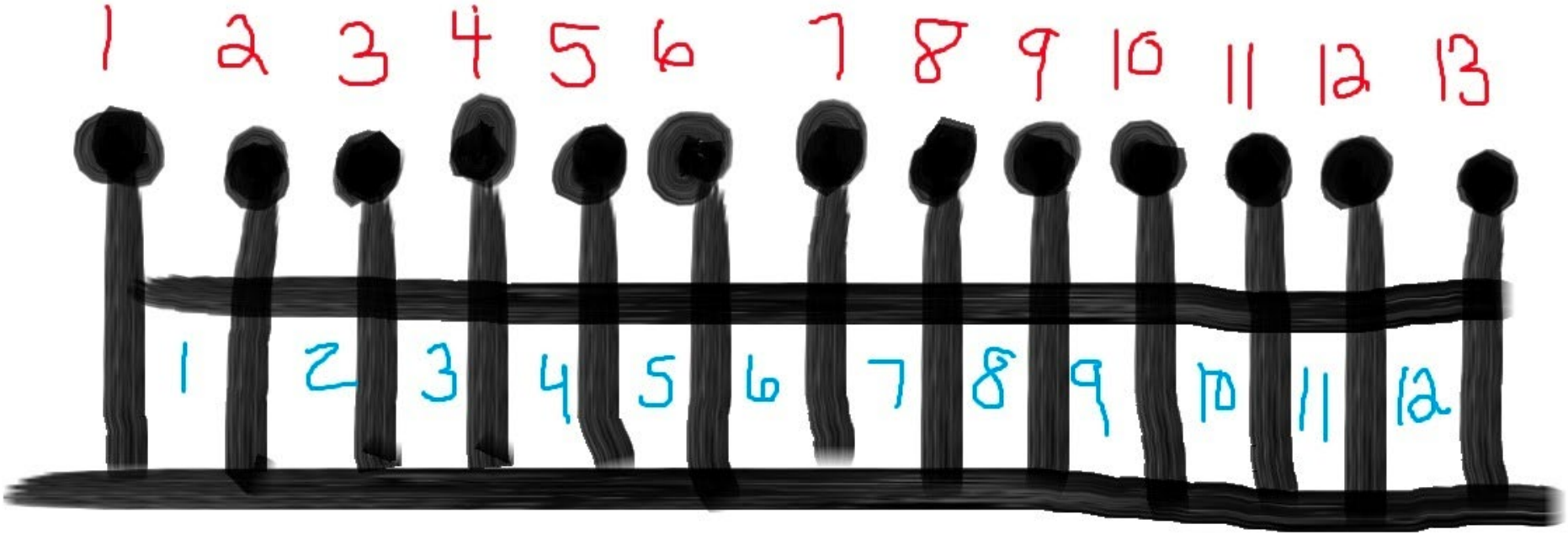
Fixed!



# Fence Post Problem




Also sometimes called an “Off By One Bug”

A program executes one line at a time.

The **`while`** loop checks its condition only at the **start** of the code block and **before repeating**.

# Which Loop

Repeat Process

**Know** how many times (definite loop)

**Don't** know how many times (indefinite loop)

`for` Loop

`while` Loop

# Actual Bug from Marc II

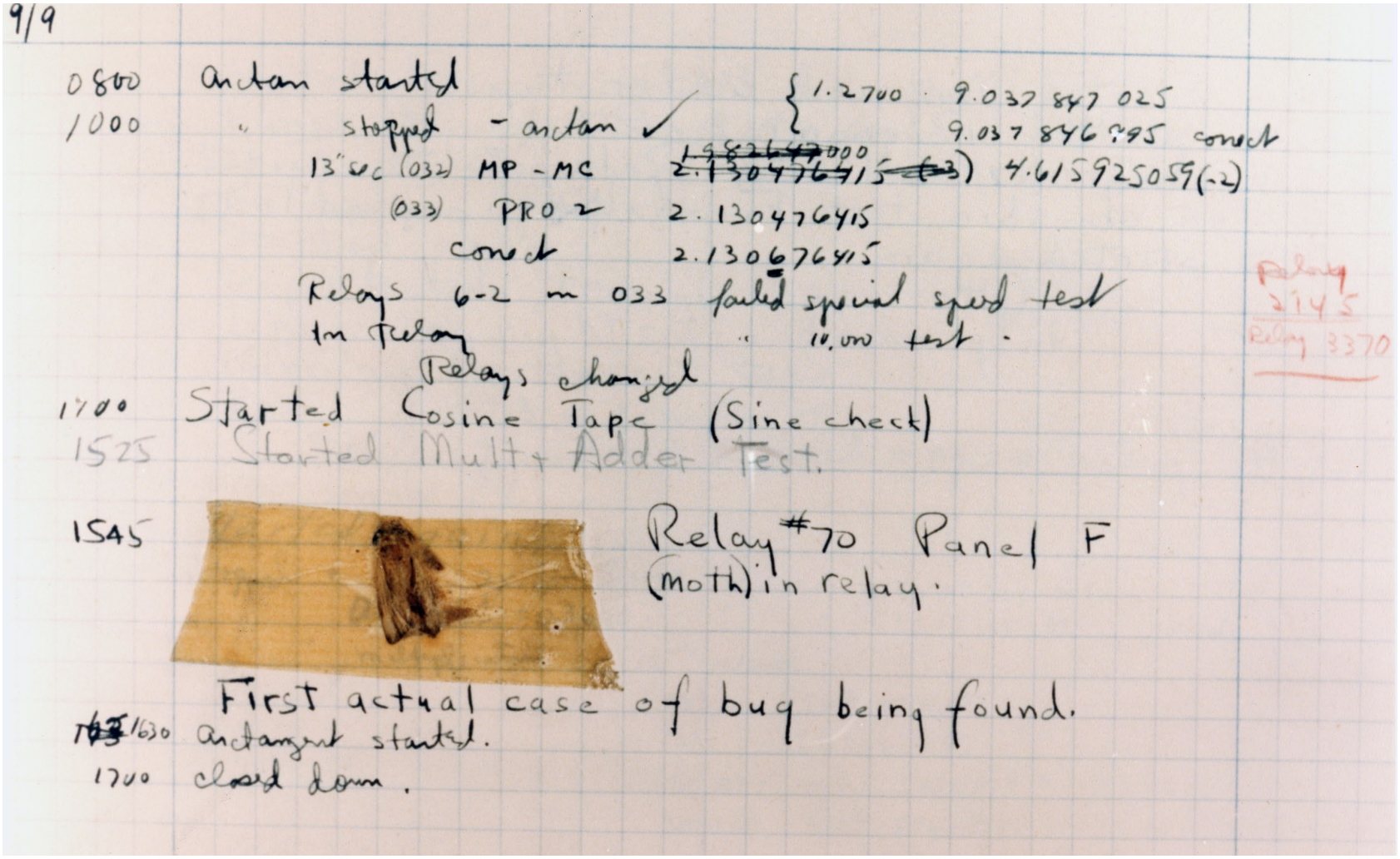



Image: First Computer Bug, 1945.jpg, Wikimedia, Public Domain, https://en.wikipedia.org/wiki/Grace_Hopper#/media/File:First_Computer_Bug,_1945.jpg

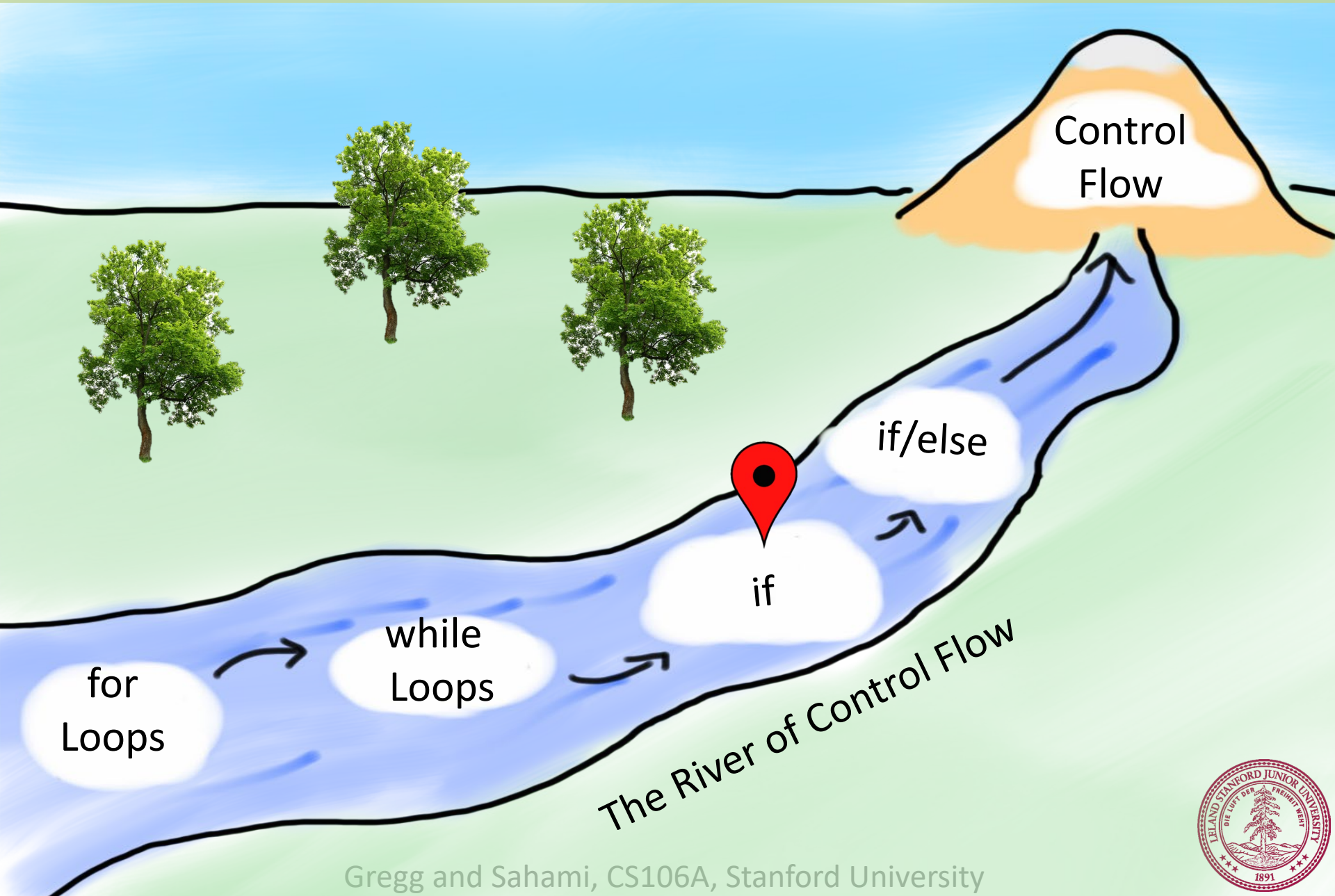
# Admiral Grace Hopper

"The most important thing I've accomplished, other than building the compiler," she said, "is training young people."

Grace Hopper college at Yale University was renamed in her honor.

Image: Commodore Grace M. Hopper, USN (covered), Wikimedia, Public Domain, https://en.wikipedia.org/wiki/Grace_Hopper#/media/File:Commodore_Grace_M._Hopper,_USN_(covered).jpg

# Today's Route



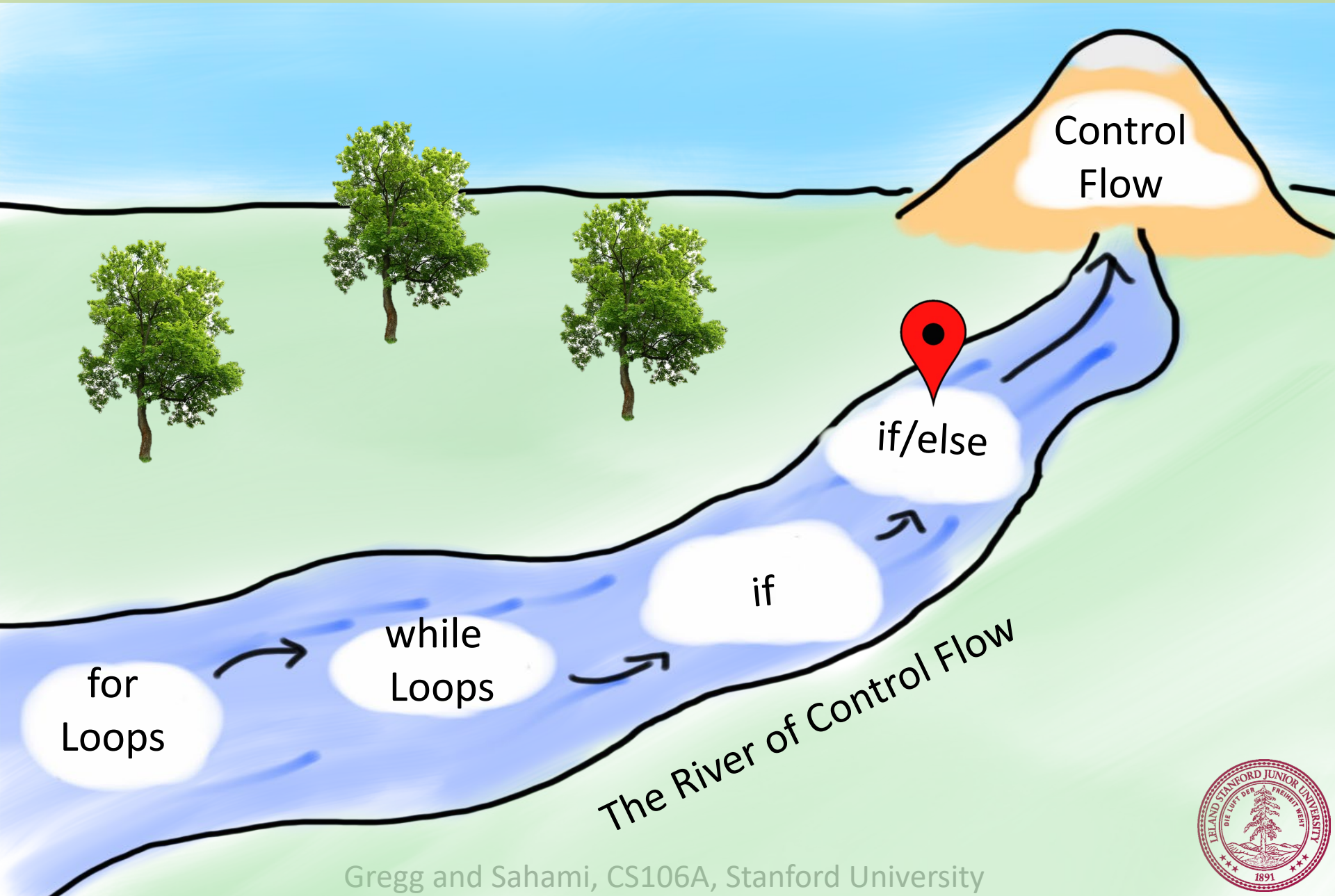
# `if` statement

```
if condition:
    statements                    # note indenting
```

---

```
def safe_pick_up():
    if beepers_present():
        pick_beeper() # note indenting
```

# Today's Route



# `if-else` statement

```
if condition:
    statements          # note indenting
else:
    statements          # note indenting
```

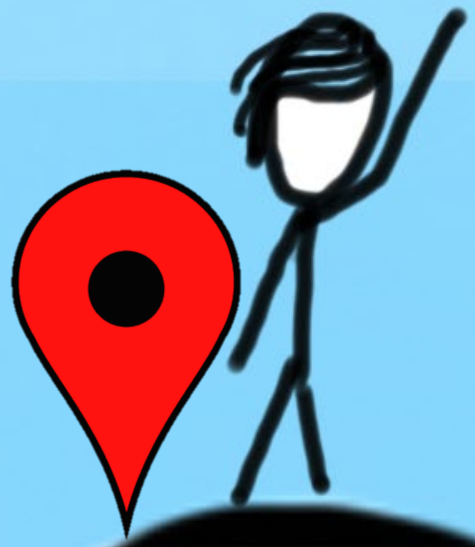
---

```
def invert_beepers():
    if beepers_present():
        pick_beeper() # note indenting
    else:
        put_beeper()  # note indenting
```

You just learned most of programming “control flow”

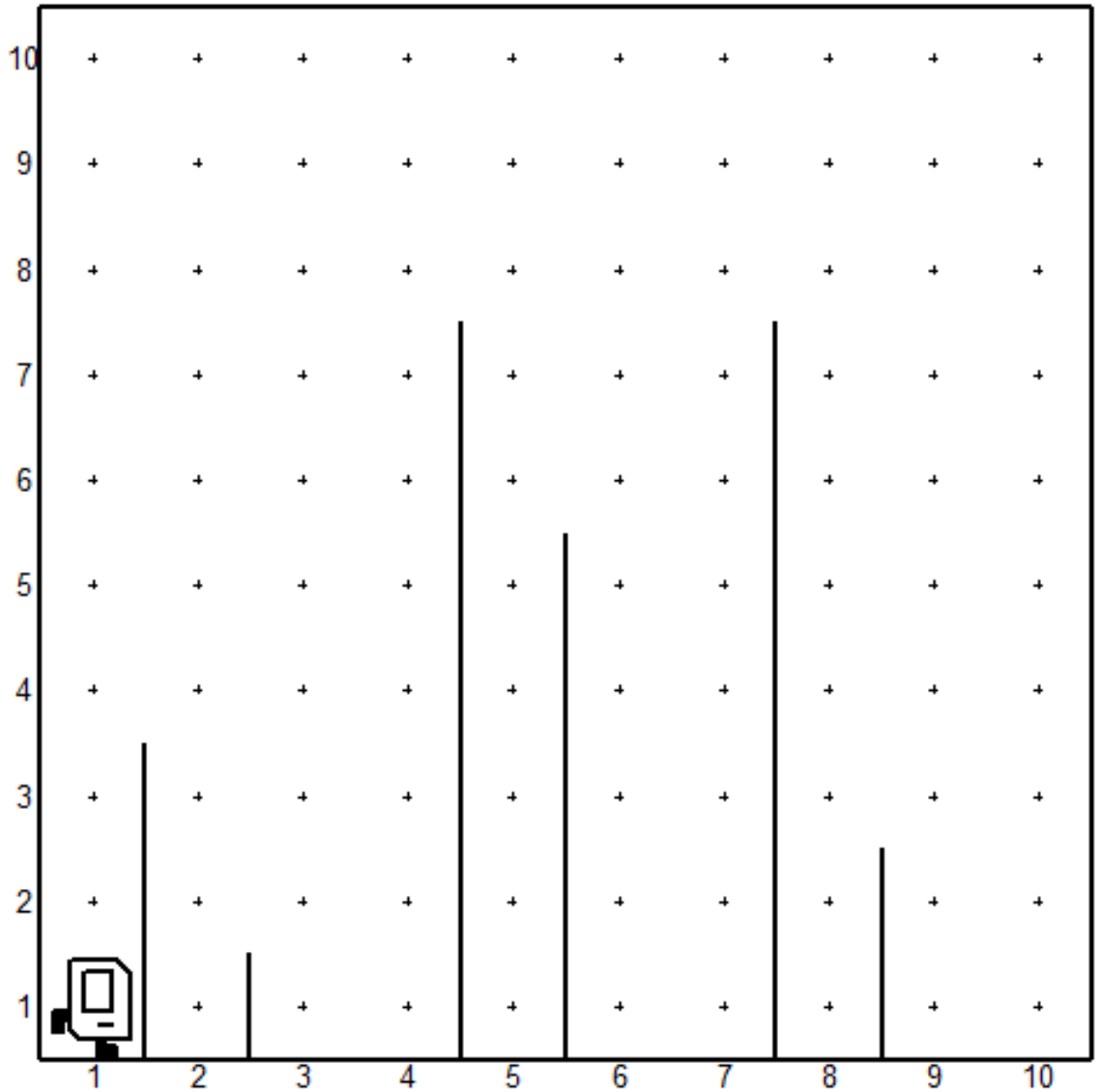
# Today's Goal

1. Code using loops and conditions
2. Trace programs that use loops and conditions

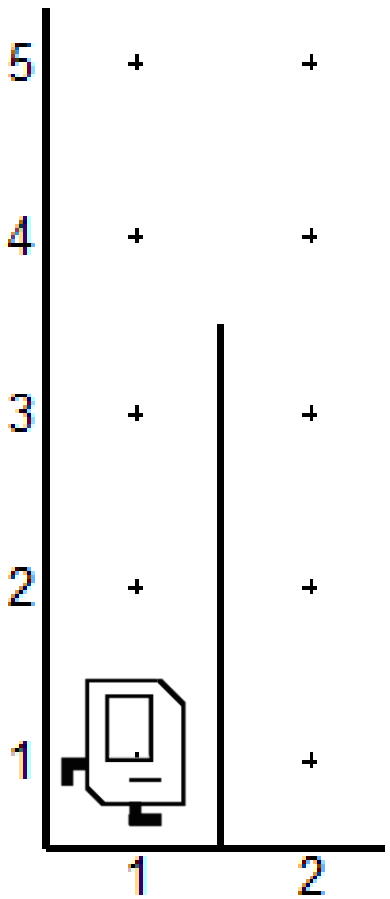


# Putting it all together
# SteepChaseKarel.py

# Steeple Chase

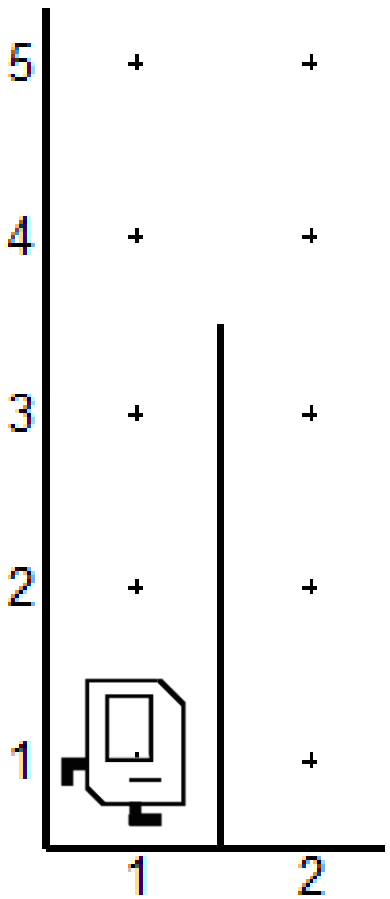


# Focus on One Steeple



# Focus on One Steeple

```
turn_left()
```



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turn_left()
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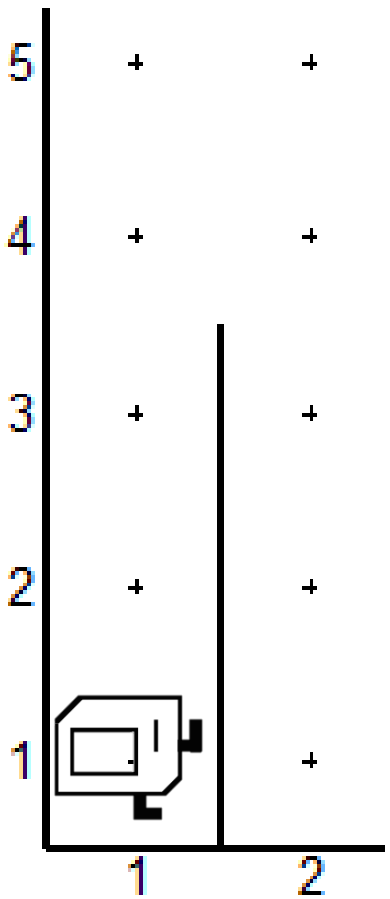

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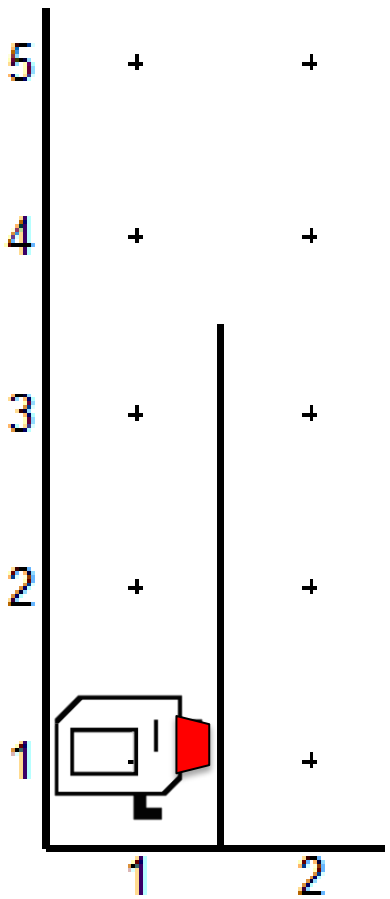
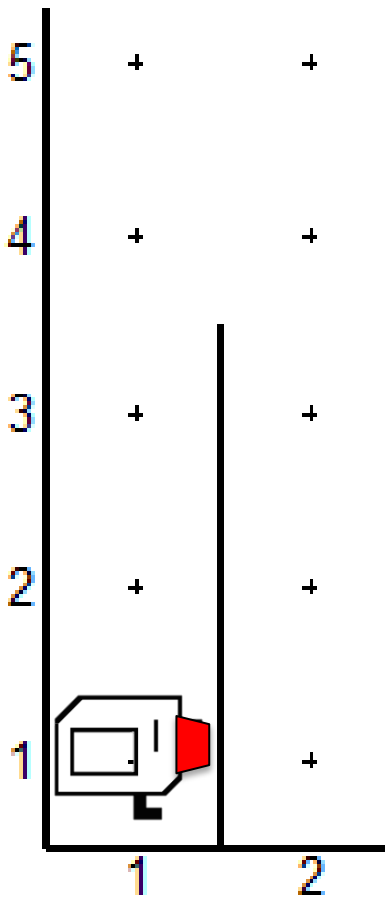



```
turn_left()
while right_is_blocked():
    move()
```

# Focus on One Steeple

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while right_is_blocked():
    move()
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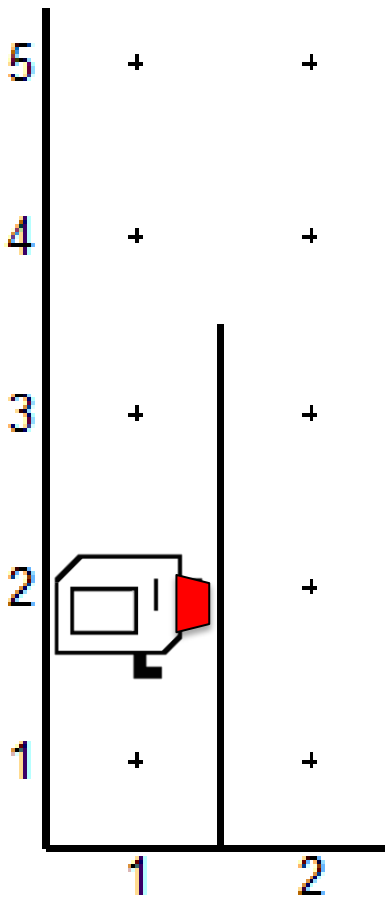


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while right_is_blocked():
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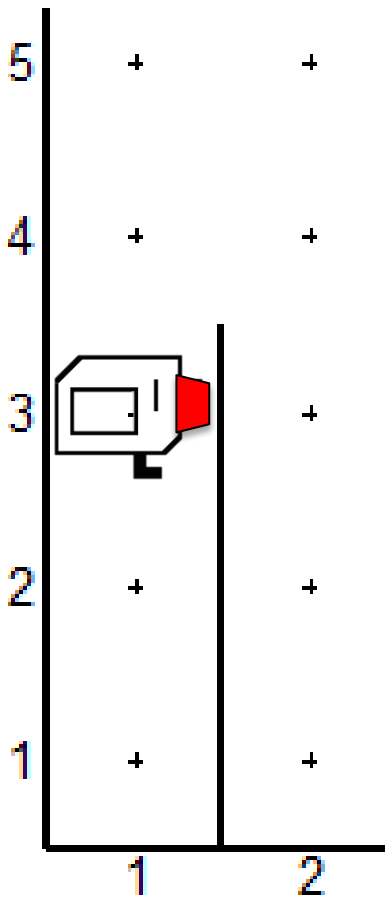


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turn_left()
while right_is_blocked():
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```

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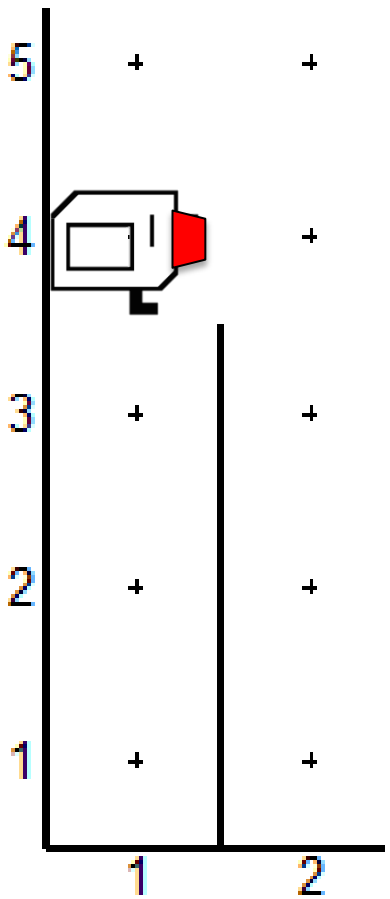


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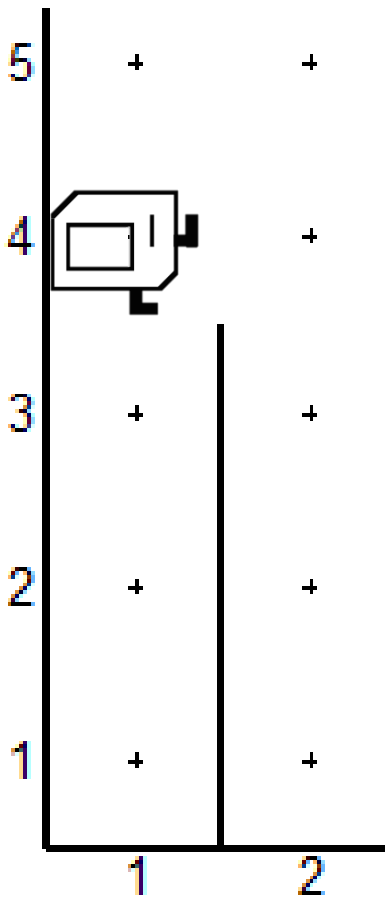
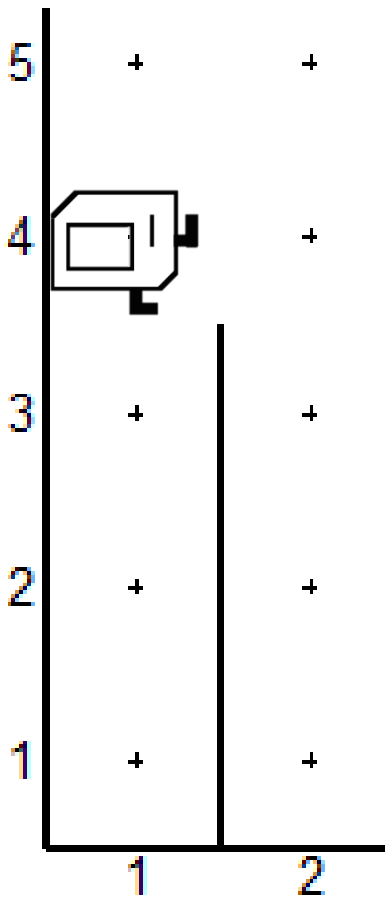


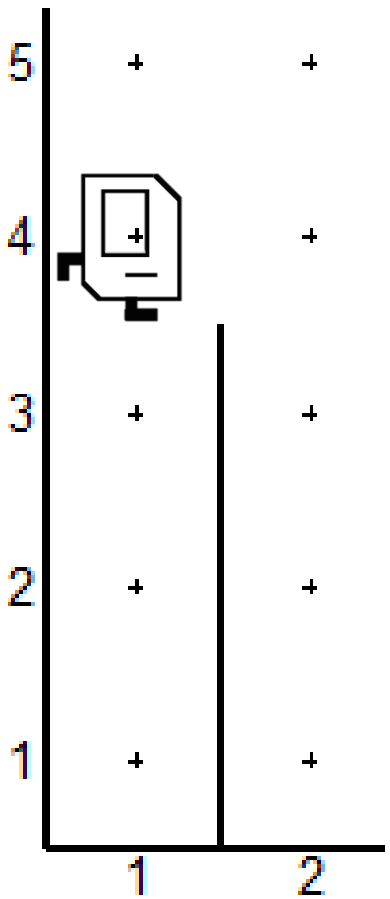

```
turn_left()
while right_is_blocked():
    move()
```

# Focus on One Steeple




```
turn_left()
while right_is_blocked():
    move()
turn_right()
```

# Focus on One Steeple

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turn_left()
while right_is_blocked():
    move()
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```

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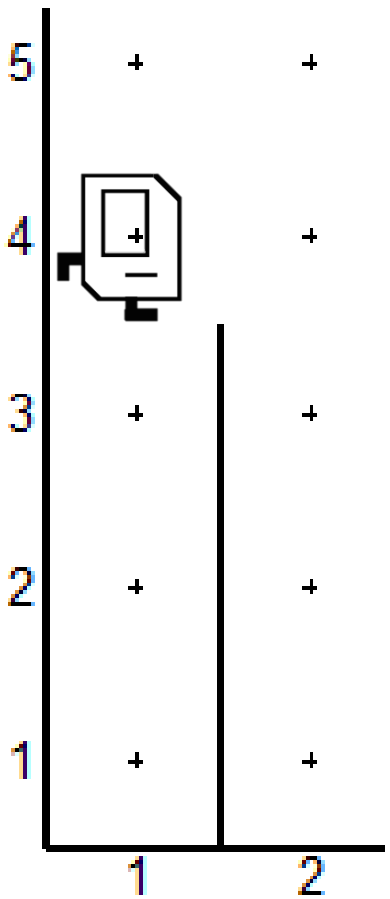


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while right_is_blocked():
    move()
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move()
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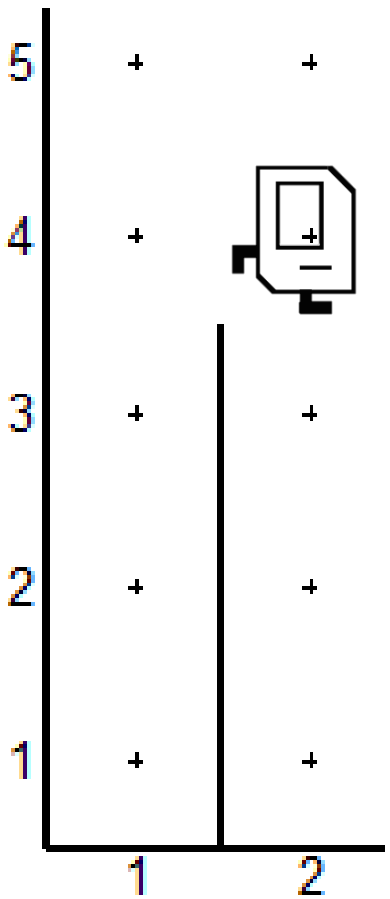


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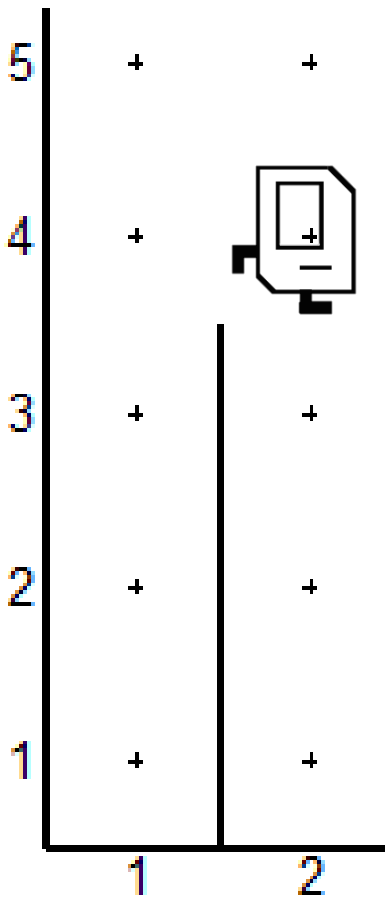
turn_left()
while right_is_blocked():
    move()
turn_right()
move()
```

# Focus on One Steeple

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turn_right()
move()
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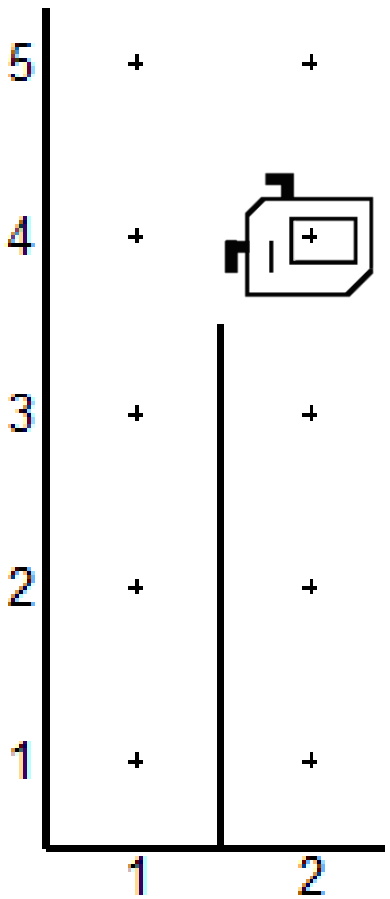


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while right_is_blocked():
    move()
turn_right()
move()
turn_right()
```

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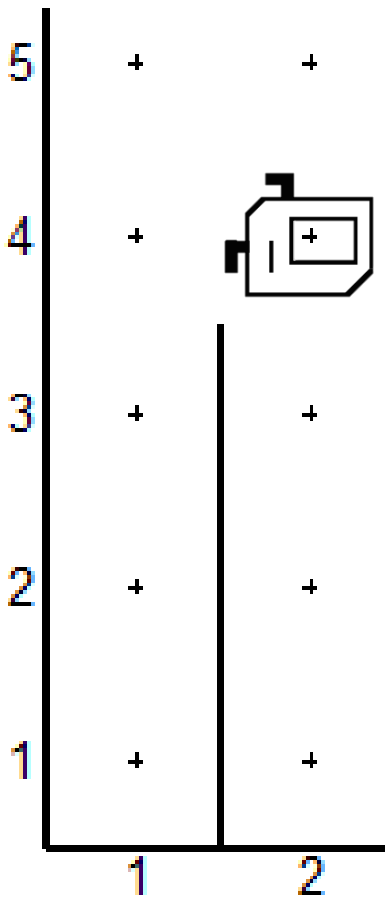
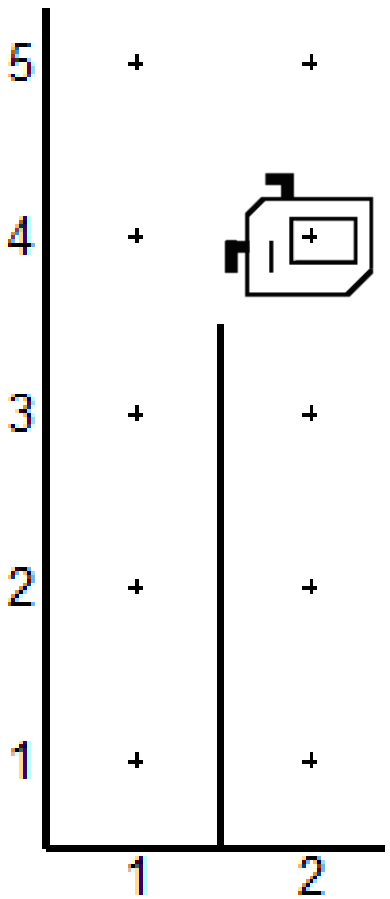



```
turn_left()
while right_is_blocked():
    move()
turn_right()
move()
turn_right()
move_to_wall()
```

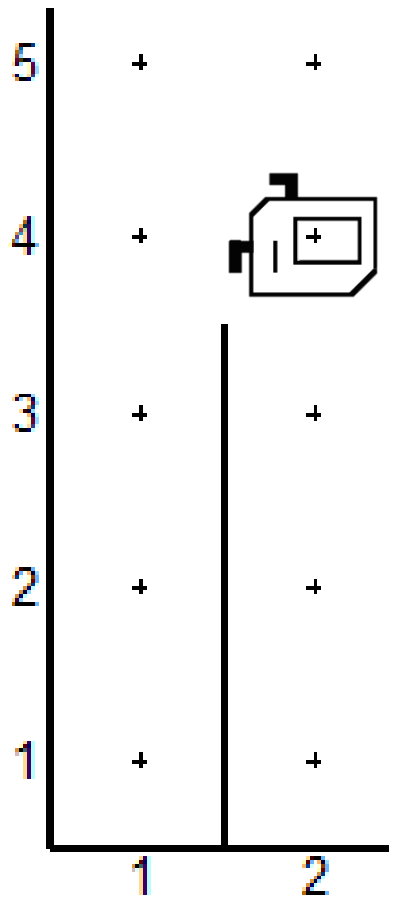
# Focus on One Steeple




```
turn_left()
while right_is_blocked():
    move()
turn_right()
move()
turn_right()
move_to_wall()
```

```
def move_to_wall():
        while front_is_clear():
            move()
```

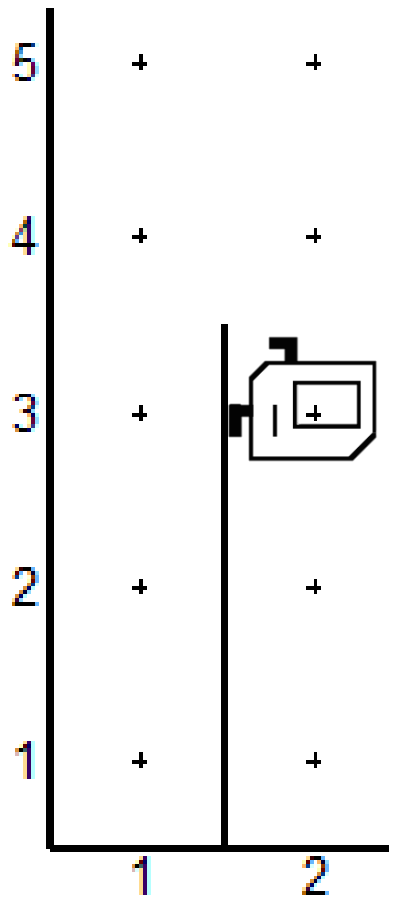
# Focus on One Steeple




```
turn_left()
while right_is_blocked():
    move()
turn_right()
move()
turn_right()
move_to_wall()
```

```
def move_to_wall():
    while front_is_clear():
        move()
```

# Focus on One Steeple

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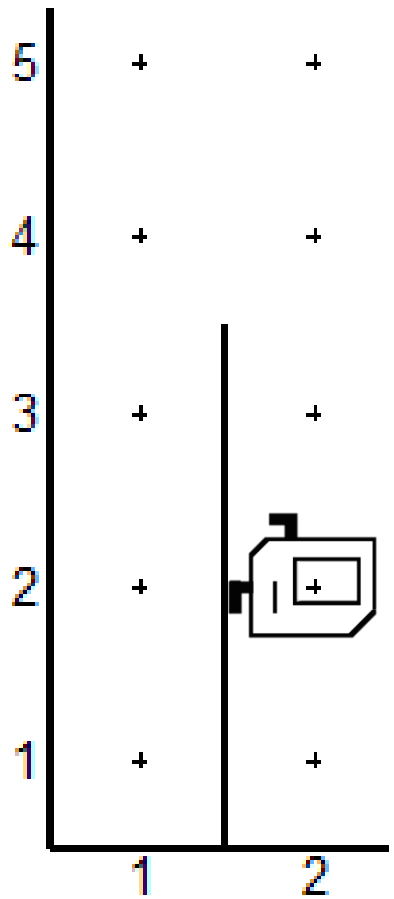
turn_left()
while right_is_blocked():
    move()
turn_right()
move()
turn_right()
move_to_wall()
```

```
def move_to_wall():
    while front_is_clear():
        move()
```

# Focus on One Steeple

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def move_to_wall():
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        move()
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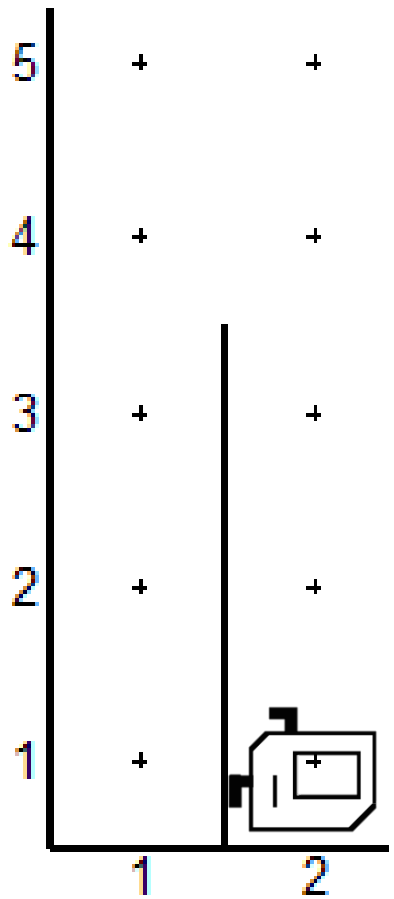


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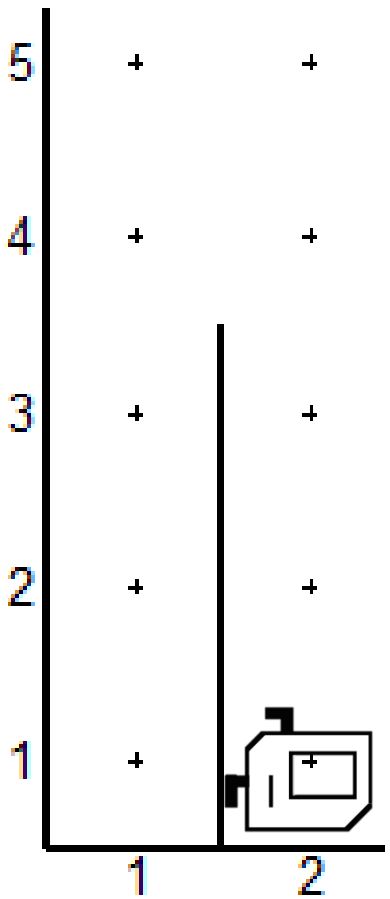
    move()
turn_right()
move()
turn_right()
move_to_wall()
```

```
def move_to_wall():
    while front_is_clear():
        move()
```

# Focus on One Steeple




```
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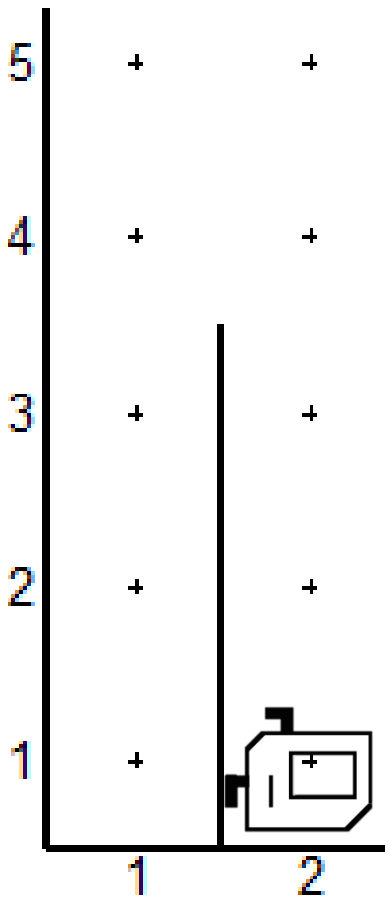
    move()
turn_right()
move()
turn_right()
move_to_wall()
```

```
def move_to_wall():
    while front_is_clear():
        move()
```

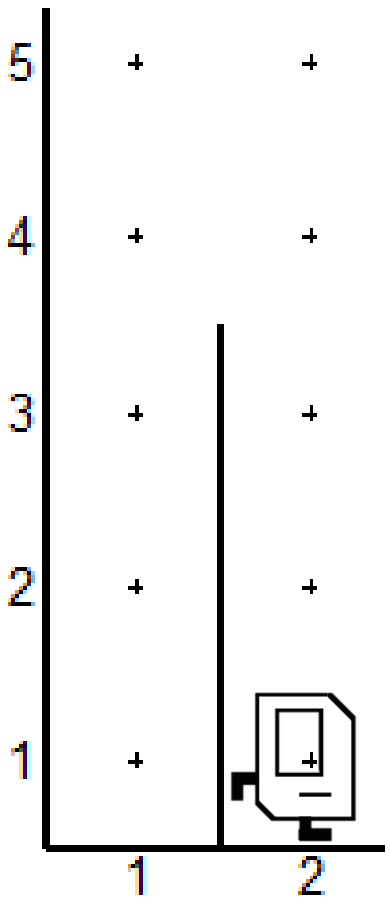
# Focus on One Steeple




```
turn_left()
while right_is_blocked():
    move()
turn_right()
move()
turn_right()
move_to_wall()
turn_left()
```

```
def move_to_wall():
        while front_is_clear():
            move()
```

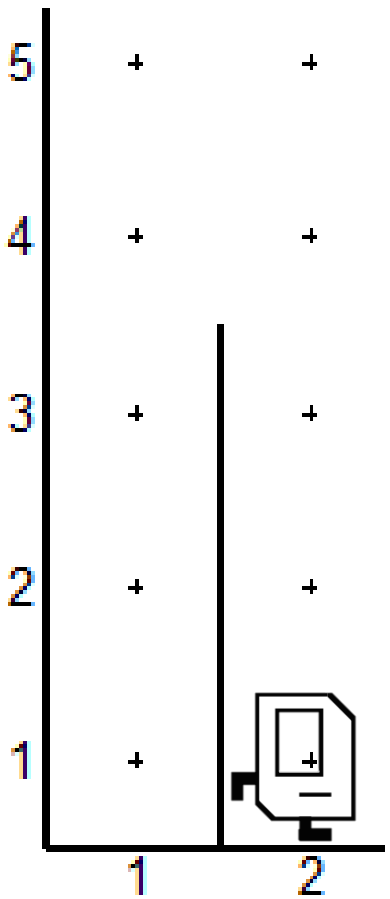
# Focus on One Steeple




```
turn_left()
while right_is_blocked():
    move()
turn_right()
move()
turn_right()
move_to_wall()
turn_left()
```

```
def move_to_wall():
    while front_is_clear():
        move()
```

# Focus on One Steeple

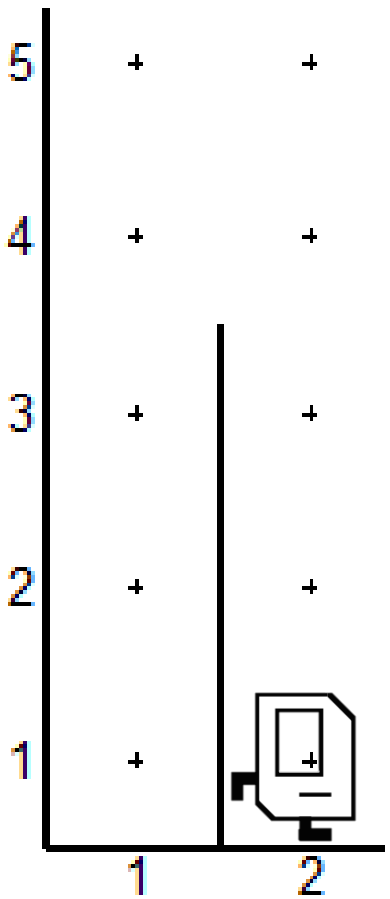



```
turn_left()
while right_is_blocked():
    move()
turn_right()
move()
turn_right()
move_to_wall()
turn_left()
```

You want the **postcondition** of a loop to match the **precondition**

```
def move_to_wall():
        while front_is_clear():
            move()
```

# Focus on One Steeple




```
turn_left()
while right_is_blocked():
    move()
turn_right()
move()
turn_right()
move_to_wall()
turn_left()
```

```
ascend_hurdle()
```

```
descend_hurdle()
```

# Focus on One Steeple

```
turn_left()
while right_is_blocked():
    move()
turn_right()
move()
turn_right()
move_to_wall()
turn_left()
```

```
ascend_hurdle()

descend_hurdle()
```

# Focus on One Steeple

```
def ascend_hurdle():
    turn_left()
    while right_is_blocked():
        move()
    turn_right()
```

```
ascend_hurdle()
move()
turn_right()
move_to_wall()
turn_left()
descend_hurdle()
```

# Focus on One Steeple

```
def ascend_hurdle():
    turn_left()
    while right_is_blocked():
        move()
    turn_right()

def descend_hurdle():
    turn_right()
    move_to_wall()
    turn_left()
```

```
ascend_hurdle()
move()
descend_hurdle()
```

# Focus on One Steeple

```
def ascend_hurdle():
    turn_left()
    while right_is_blocked():
        move()
    turn_right()

def descend_hurdle():
    turn_right()
    move_to_wall()
    turn_left()

def jump_hurdle():
    ascend_hurdle()
    move()
    descend_hurdle()
```

# A Whole Program: SteepleChaseKarel.py