Functions

CS Bridge 2020

Learn How To:

1. Write a function that takes in input
2. Write a function that gives back output
3. Trace function calls using stacks

Lecture Plan

- Functions: From Karel to Python
- **Example**: Factorial
- More About Functions
- **Example**: Graphics

Lecture Plan

- **Functions: From Karel to Python**
- **Example**: Factorial
- More About Functions
- **Example**: Graphics

Calling functions

```
turn_right()
```

```
move()
```

```
input("string please! ")
```

```
print("hello world")
```

```
float("0.42")
```

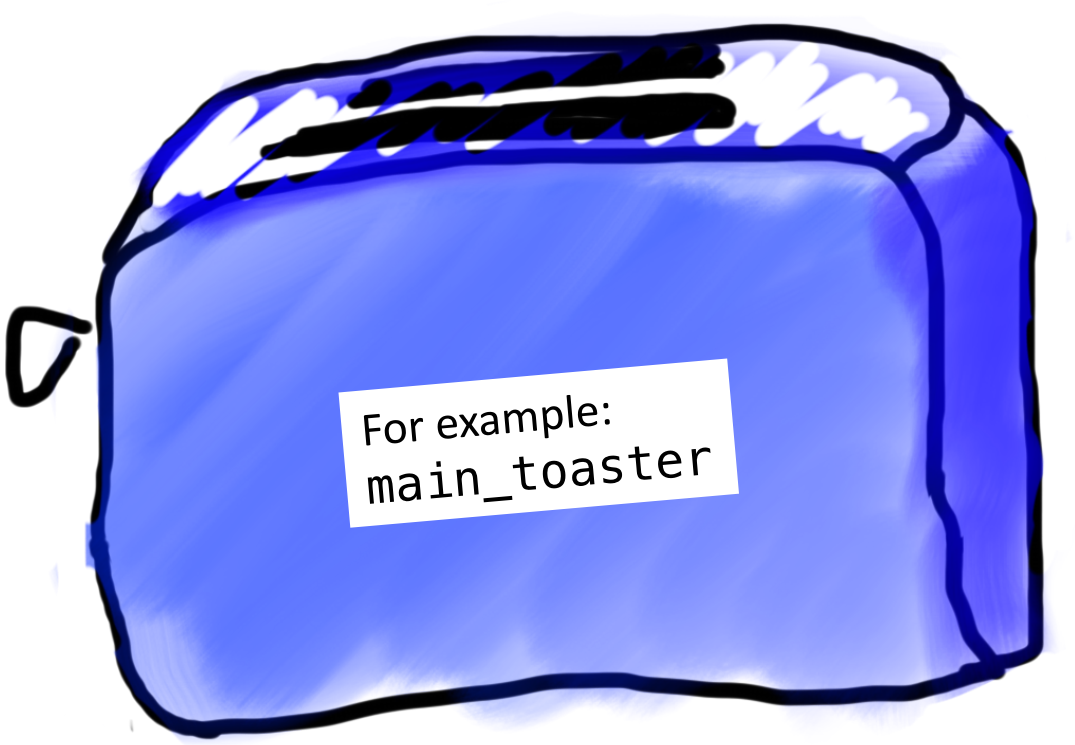
```
math.sqrt(25)
```


Defining a function

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

Big difference with python functions:
Python functions can **take in data**, and can **return data**!

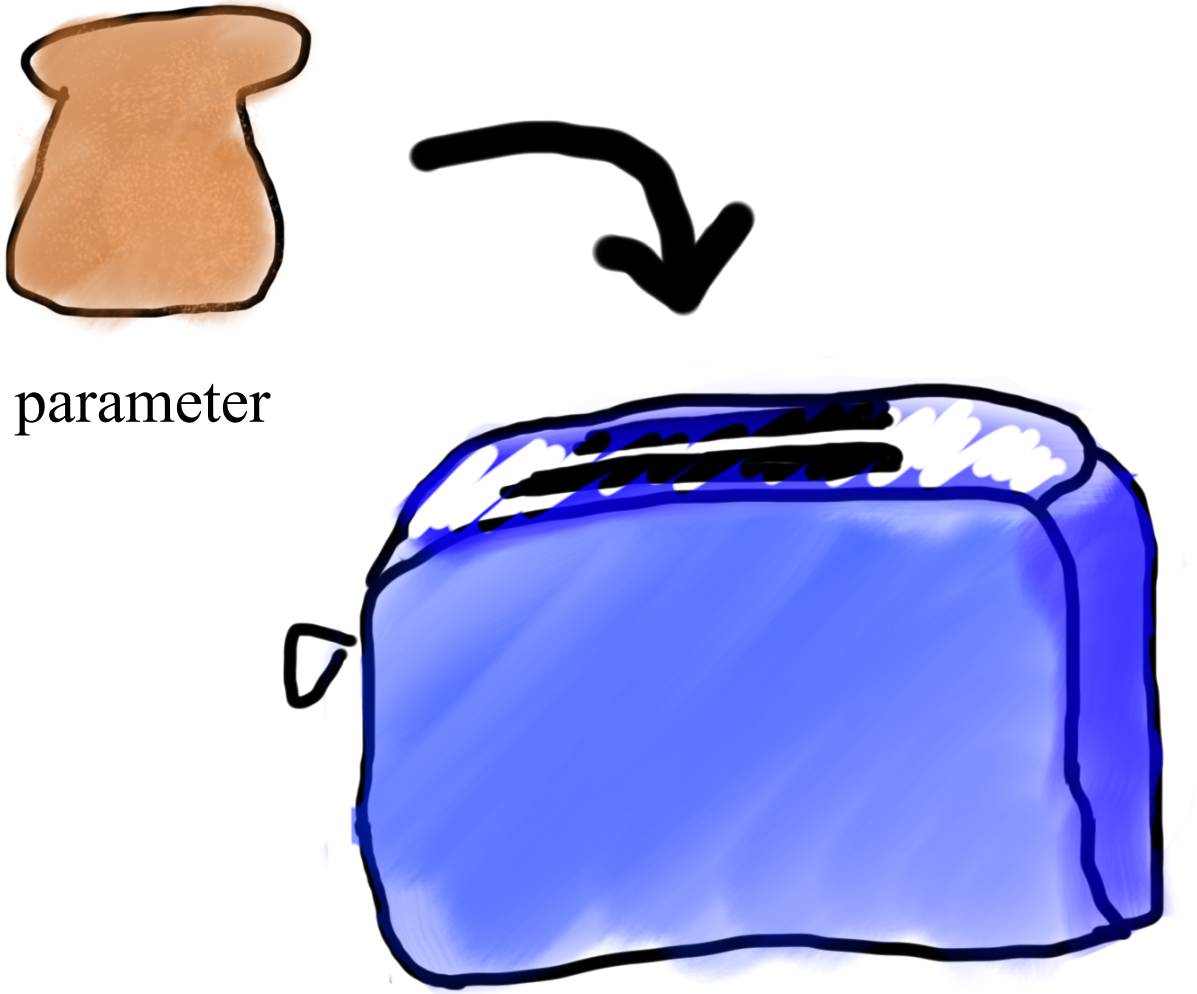
Toasters are functions



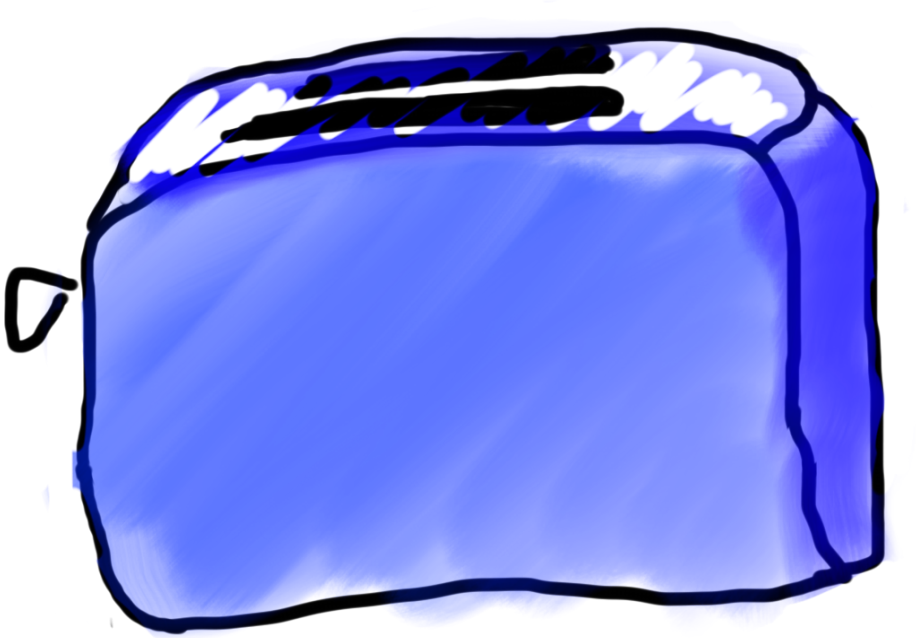
Toasters are functions

parameter

Toasters are functions

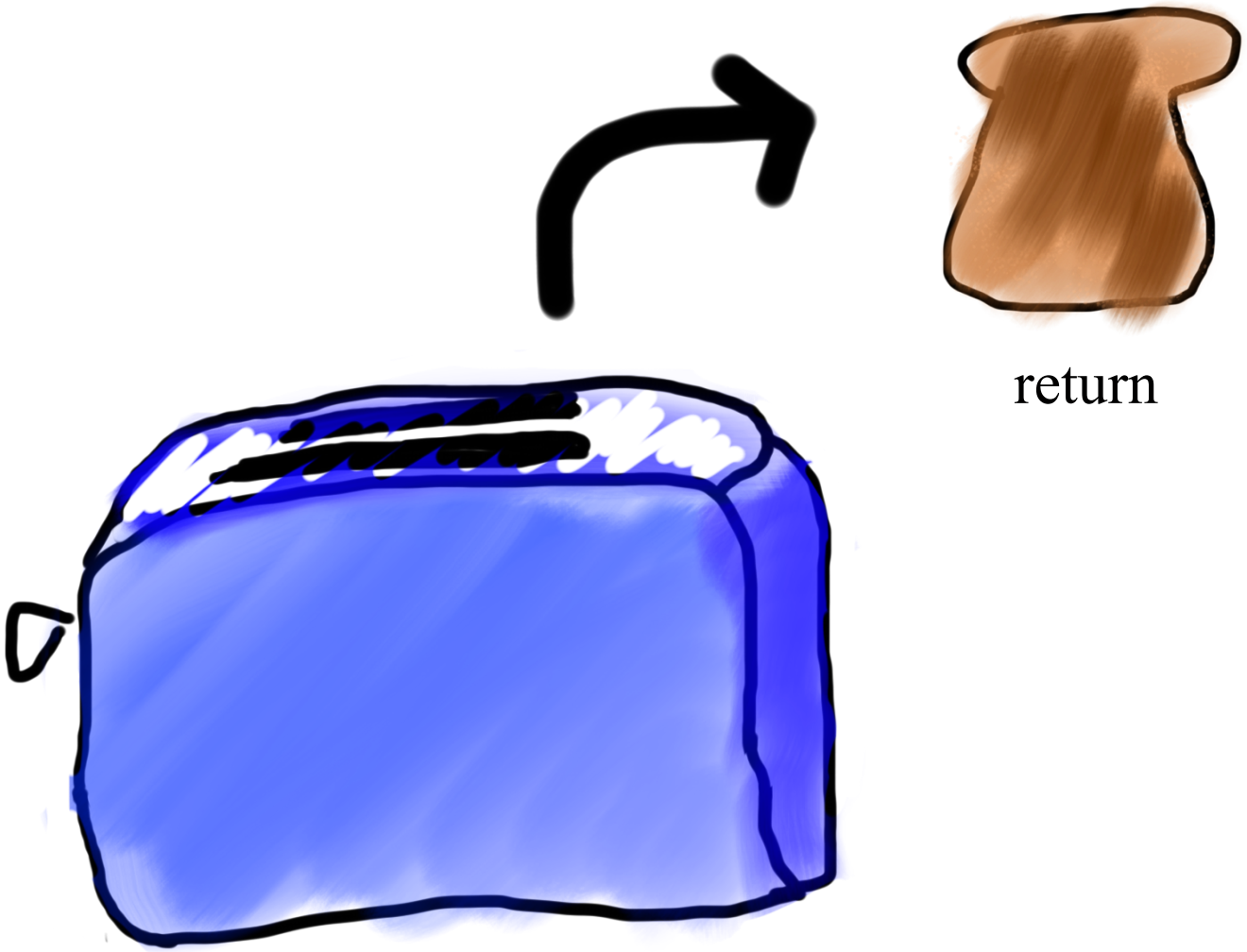


Toasters are functions



Toasters are functions

Toasters are functions



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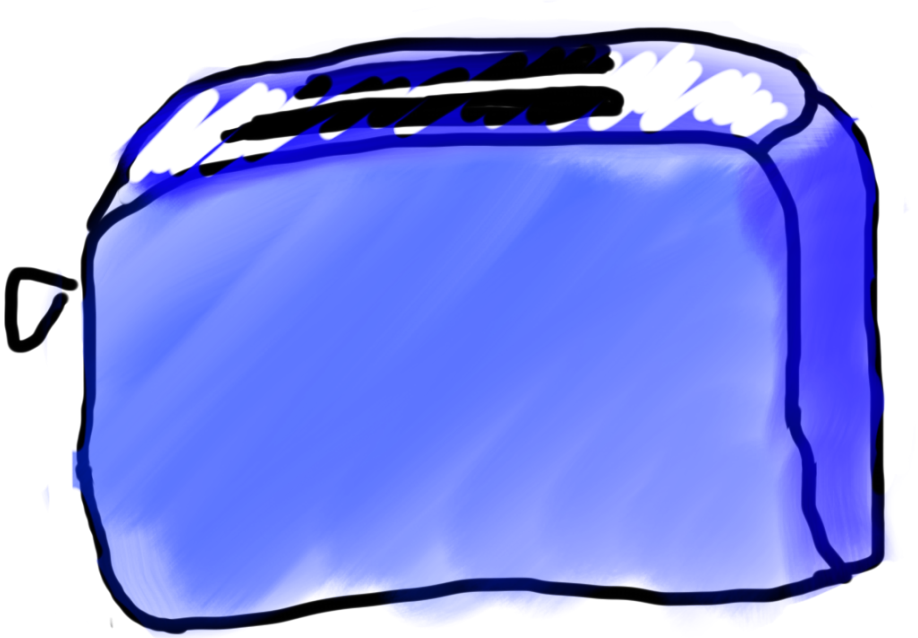

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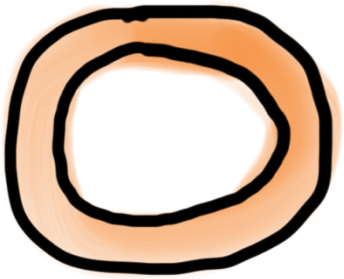
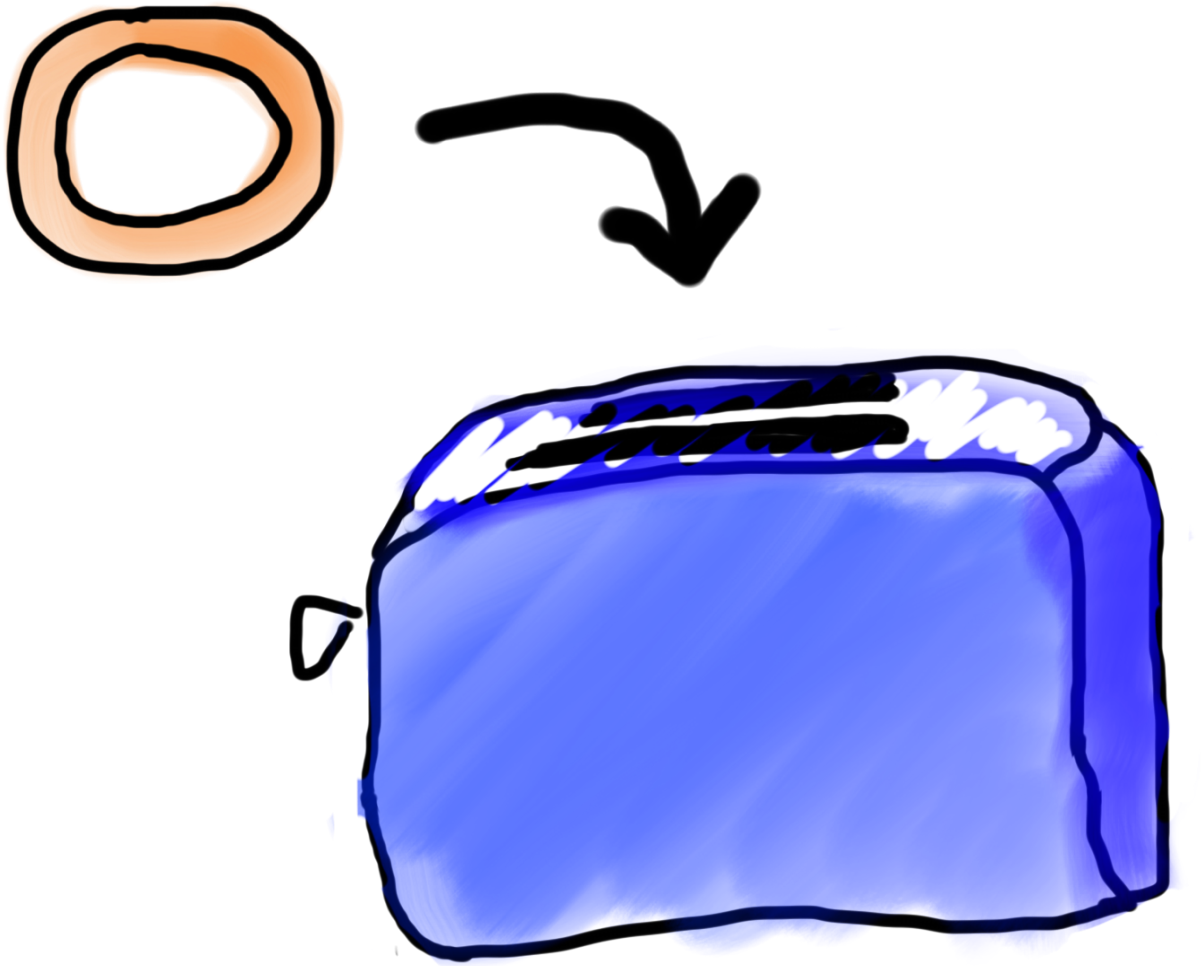


* You don’t need a second toaster if you want to toast bagels. Use the same one.

Toasters are functions



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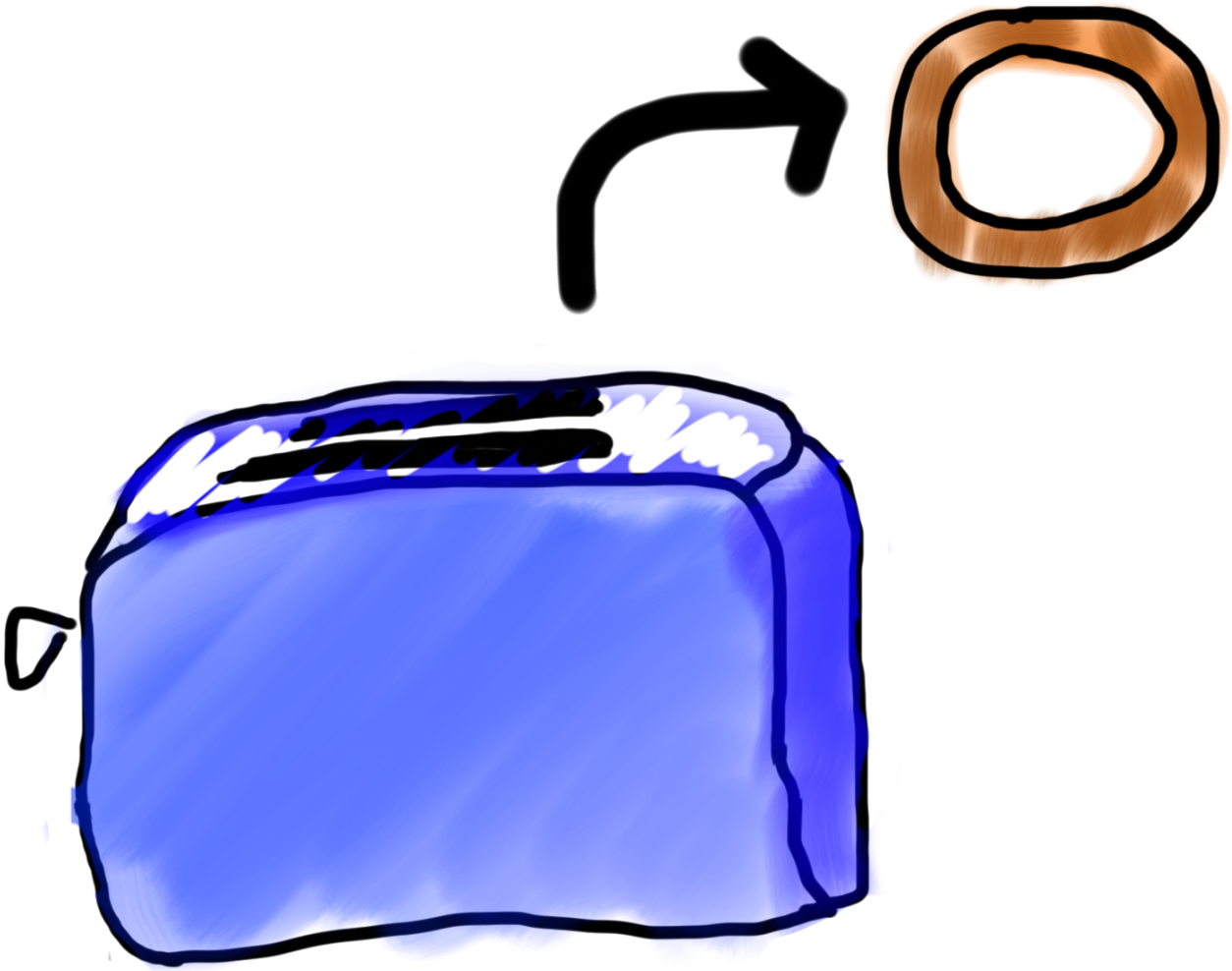

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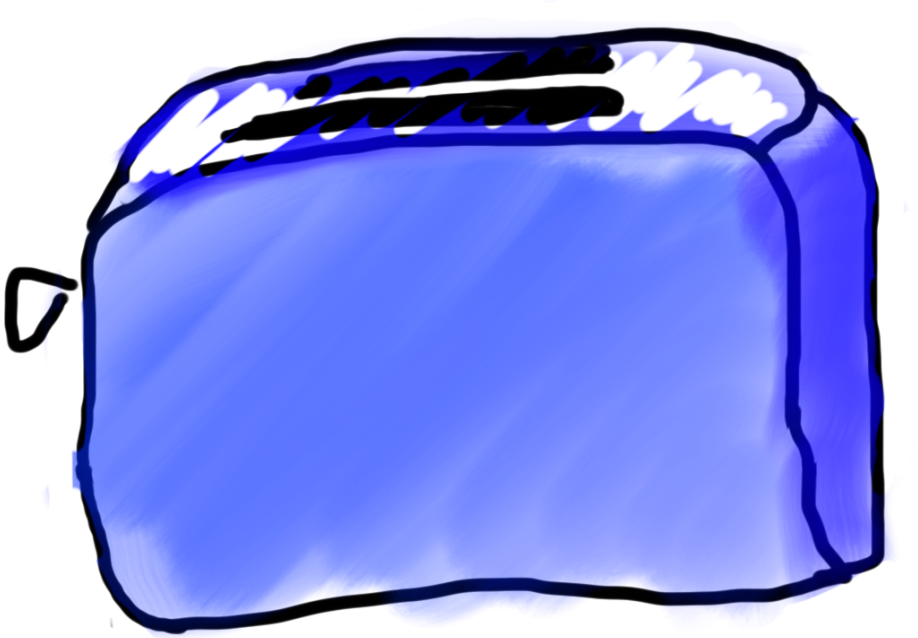

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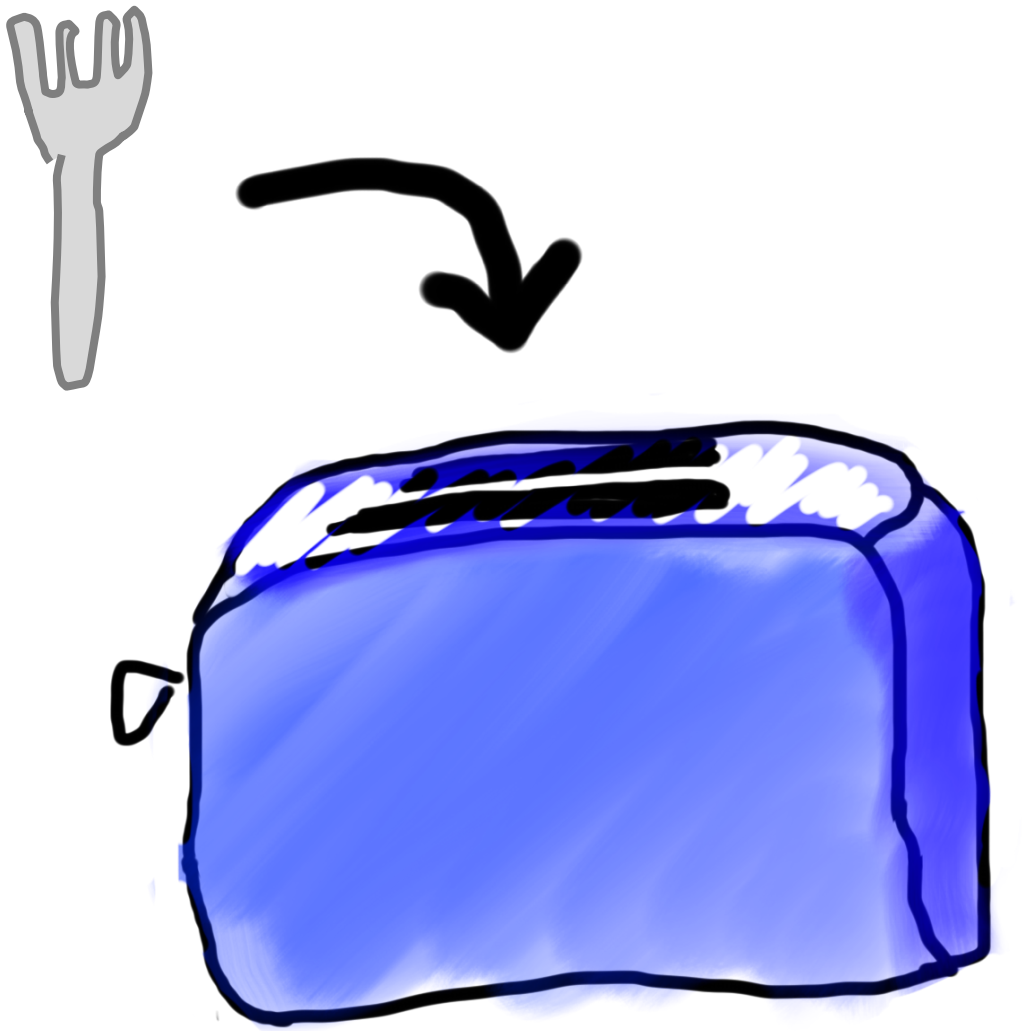
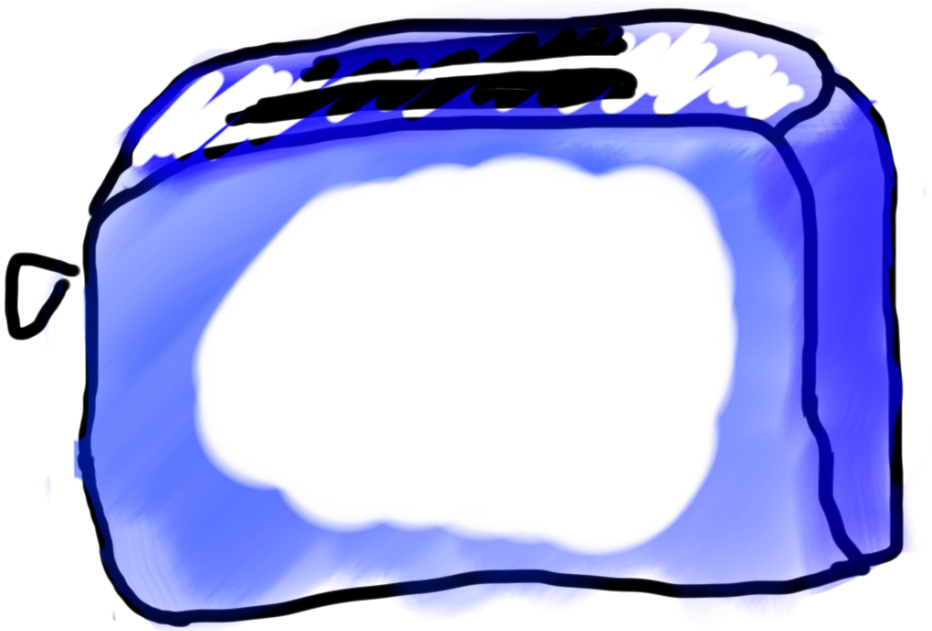


Toasters are functions

functions are Like Toasters

functions are Like Toasters



functions are Like Toasters

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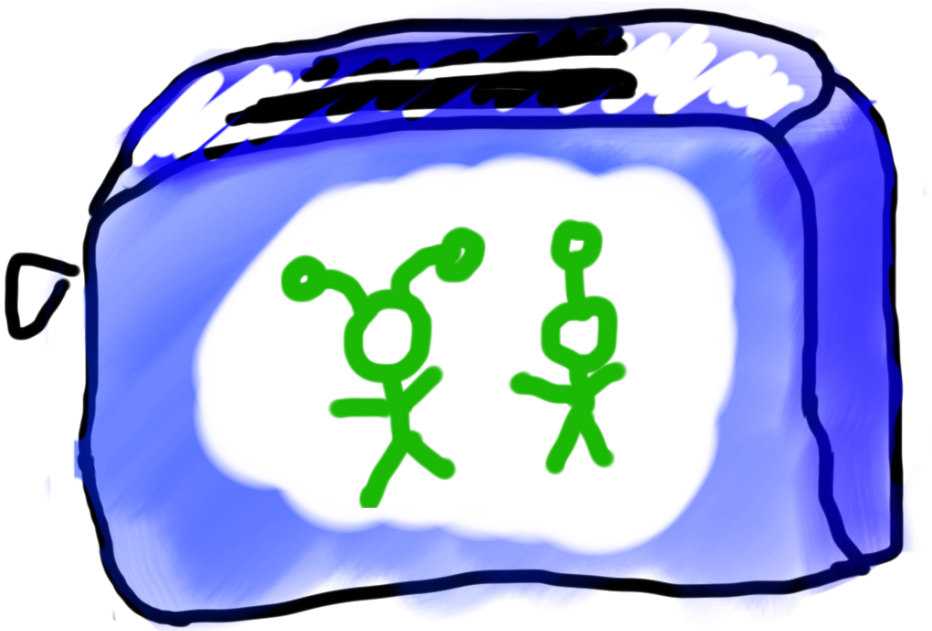
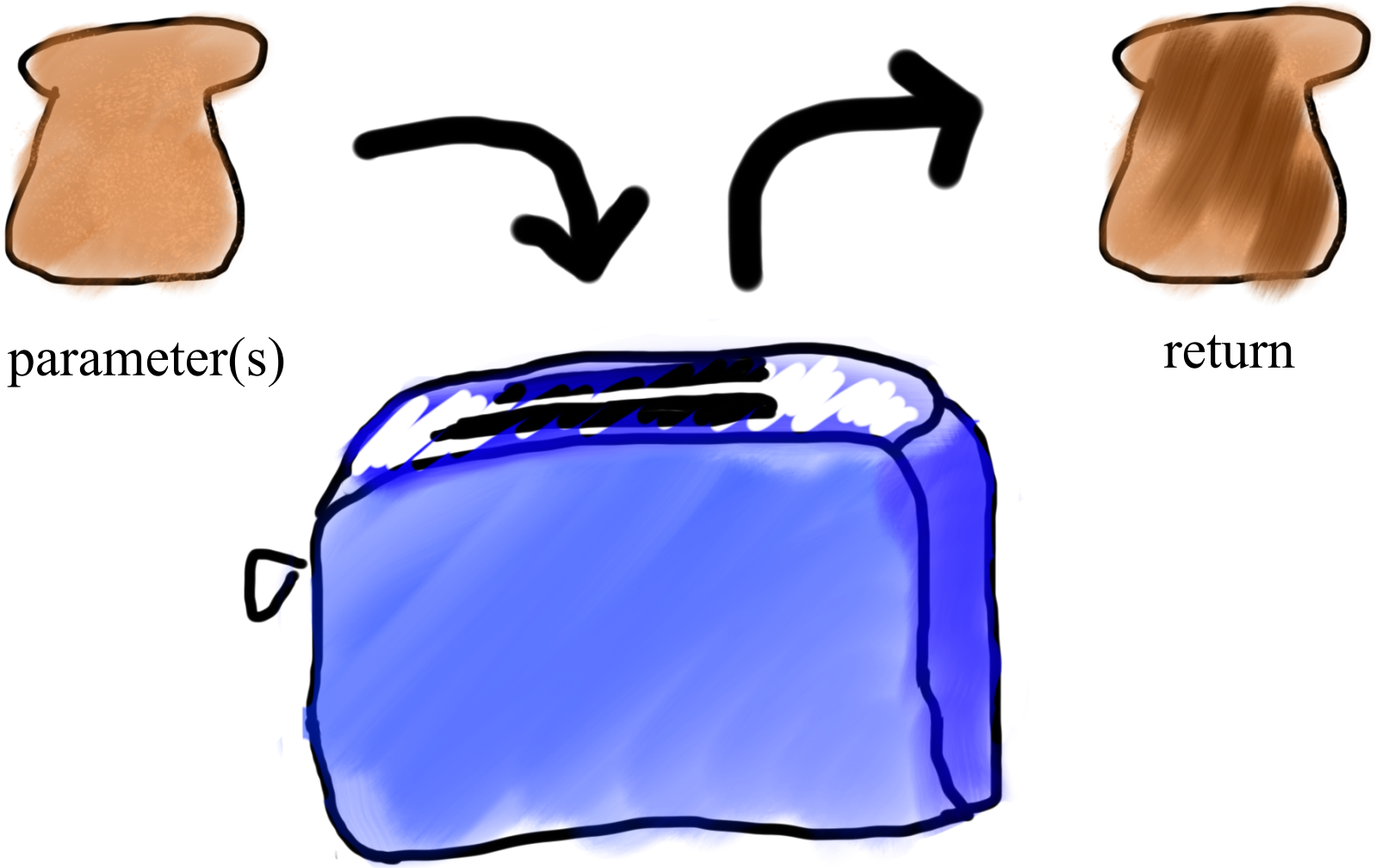


functions are Like Toasters



Formally

```
def name_of_function(parameters):
    statements
    # optionally
    return value
```

- ***name:*** information passed into function
- ***parameters:*** information passed into function
- ***return*:** information given back from the function

Classic Challenge

Perhaps the most underrated concept by students

Anatomy of a function

```
def main():
    mid = average(5.0, 10.2)
    print(mid)


def average(a, b):
    sum = a + b
    return sum / 2
```

Anatomy of a function

```
def main():
    mid = average(5.0, 10.2)
    print(mid)
```

function "call"

function "definition"

```
def average(a, b):
    sum = a + b
    return sum / 2
```


Anatomy of a function

```
def main():
    mid = average(5.0, 10.2)
    print(mid)
```

name

```
def average(a, b):
    sum = a + b
    return sum / 2
```

Anatomy of a function

Input given

```
def main():
    mid = average(5.0, 10.2)
    print(mid)
```

Input expected

```
def average(a, b):
    sum = a + b
    return sum / 2
```


Anatomy of a function

```
def main():
    mid = average(5.0, 10.2)
    print(mid)
```

Arguments

```
def average(a, b):
    sum = a + b
    return sum / 2
```

Parameters

Anatomy of a function

```
def main():
    mid = average(5.0, 10.2)
    print(mid)
```

```
def average(a, b):
    sum = a + b
    return sum / 2
```

body

Anatomy of a function

```
def main():
    mid = average(5.0, 10.2)
    print(mid)
```

This call "evaluates" to the value returned

```
def average(a, b):
    sum = a + b
    return sum / 2
```

Ends the function and gives back a value

Anatomy of a function

Also a function definition

```
def main():
    mid = average(5.0, 10.2)
    print(mid)
```

```
def average(a, b):
    sum = a + b
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```

Anatomy of a function

No parameters (expects no input)

```
def main():
    mid = average(5.0, 10.2)
    print(mid)
```

```
def average(a, b):
    sum = a + b
    return sum / 2
```


Anatomy of a function

```
def main():
    mid = average(5.0, 10.2)
    print(mid)
```

When a function ends it "returns"

```
def average(a, b):
    sum = a + b
    return sum / 2
```

Parameters

Parameters let you provide a function some information when you are calling it.

Is returning
the same as printing?

Is returning
the same as printing?

NO

Learn by Example

Lecture Plan

- Functions: From Karel to Python
  - **no parameter, no return**
  - parameter
  - parameter and return
- **Example**: Factorial
- More About Functions
- **Example**: Graphics

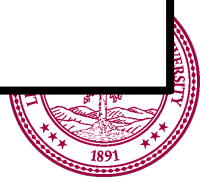
No Parameter, No Return

```
def print_intro():
    print("Welcome to class")
    print("It's the best part of my day.")


def main():
    print_intro()
```

terminal

```
> python3 intro.py
```



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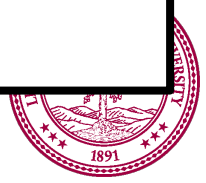

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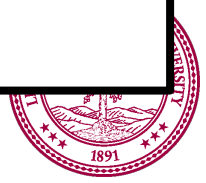

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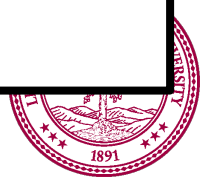

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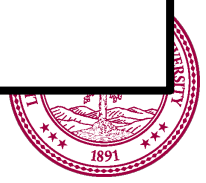

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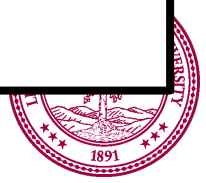

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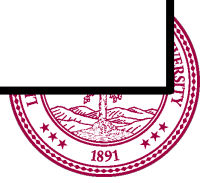

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Lecture Plan

- Functions: From Karel to Python
  - no parameter, no return
  - **parameter**
  - parameter and return
- **Example**: Factorial
- More About Functions
- **Example**: Graphics

Parameter Example

```
def print_opinion(num):
    if(num == 5):
        print("I love 5!")
    else :
        print("Whatever")


def main():
    print_opinion(5)
```

terminal

```
> python3 opinion.py
```

Parameter Example

main memory

No variables

terminal

> python3 opinion.py

```
def print_opinion(num):
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Parameter Example

main memory

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Parameter Example

main memory

No variables

print_opinion memory

terminal

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> python3 opinion.py
```

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Parameter Example

main memory

No variables

print_opinion memory

num

terminal

```
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```
def print_opinion(num):
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def main():
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```

Parameter Example

main memory

No variables

print_opinion memory

num **5**

terminal

> python3 opinion.py

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Parameter Example

main memory

No variables

print_opinion memory

num 5

terminal

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Parameter Example

main memory

No variables

print_opinion memory

num 5

terminal

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Parameter Example

main memory

No variables

print_opinion memory

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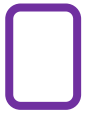

Parameter Example

main memory

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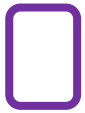

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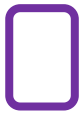

Lecture Plan

- Functions: From Karel to Python
  - no parameter, no return
  - parameter
  - **parameter and return**
- **Example**: Factorial
- More About Functions
- **Example**: Graphics

Parameter and Return Example

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    result = meters_to_cm(5.2)
    print(result)
```

terminal

```
> python3 m2cm.py
```

Parameter and Return Example

main memory

No variables

terminal

```
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```

```
def meters_to_cm(meters):
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```

Parameter and Return Example

main memory

No variables

meters_to_cm memory

terminal

```
> python3 m2cm.py
```

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    result = meters_to_cm(5.2)
    print(result)
```

Parameter and Return Example

main memory

No variables

meters_to_cm memory

meters 5.2

terminal

```
> python3 m2cm.py
```

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    result = meters_to_cm(5.2)
    print(result)
```

Parameter and Return Example

main memory

No variables

meters_to_cm memory

meters | 5.2

terminal

> python3 m2cm.py

```
def meters_to_cm(meters):
    return 100 * meters
```

520.0

```
def main():
    result = meters_to_cm(5.2)
    print(result)
```

Parameter and Return Example

main memory

No variables

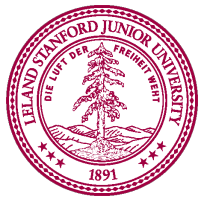
terminal

> python3 m2cm.py

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    result = meters_to_cm(5.2)
    print(result)
```

520.0



Parameter and Return Example

main memory

terminal

```
> python3 m2cm.py
```

```
def meters_to_cm(meters):
    return 100 * meters

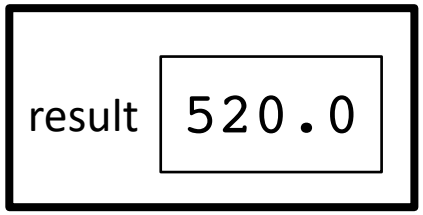


def main():
    result = meters_to_cm(5.2)
    print(result)
```

520.0

Parameter and Return Example

main memory



terminal

```
> python3 m2cm.py
520.0
```

```
def meters_to_cm(meters):
    return 100 * meters



def main():
    result = meters_to_cm(5.2)
    print(result)
```

Parameter and Return Example

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    print(meters_to_cm(5.2))
    print(meters_to_cm(9.1))
```

terminal

```
> python3 m2cm.py
```

Parameter and Return Example

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    print(meters_to_cm(5.2))
    print(meters_to_cm(9.1))
```

terminal

```
> python3 m2cm.py
```

If a method returns something, you can use it directly in an expression!

Parameter and Return Example

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    print(meters_to_cm(5.2))
    print(meters_to_cm(9.1))
```

terminal

```
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```

Parameter and Return Example

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    print(meters_to_cm(5.2))
    print(meters_to_cm(9.1))
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terminal

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Parameter and Return Example

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def main():
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520.0

terminal

```
> python3 m2cm.py
```

Parameter and Return Example

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    print(meters_to_cm(5.2))
    print(meters_to_cm(9.1))
```

520.0

terminal

```
> python3 m2cm.py
520.0
```

Parameter and Return Example

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    print(meters_to_cm(5.2))
    print(meters_to_cm(9.1))
```

terminal

```
> python3 m2cm.py
520.0
```

Parameter and Return Example

```
def meters_to_cm(meters):
    return 100 * meters


def main():
    print(meters_to_cm(5.2))
    print(meters_to_cm(9.1))
```

910.0

terminal

```
> python3 m2cm.py
520.0
```

Parameter and Return Example

```
def meters_to_cm(meters):
    return 100 * meters
```

```
def main():
    print(meters_to_cm(5.2))
    print(meters_to_cm(9.1))
```

910.0

terminal

```
> python3 m2cm.py
520.0
910.0
```

Contrasting Case:

```
# How is this function
def meters_to_cm_case1(meters):
    return 100 * meters
```

```
# Different than this function?
def meters_to_cm_case2(meters):
    print(100 * meters)
```


Is returning
the same as printing?

Is returning
the same as printing?

NO

Multiple Return Statements

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2


def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory

No variables

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2


def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory

No variables

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2


def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory

No variables

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```


Multiple Return Statements

main memory

No variables

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```


Multiple Return Statements

main memory

No variables

max memory

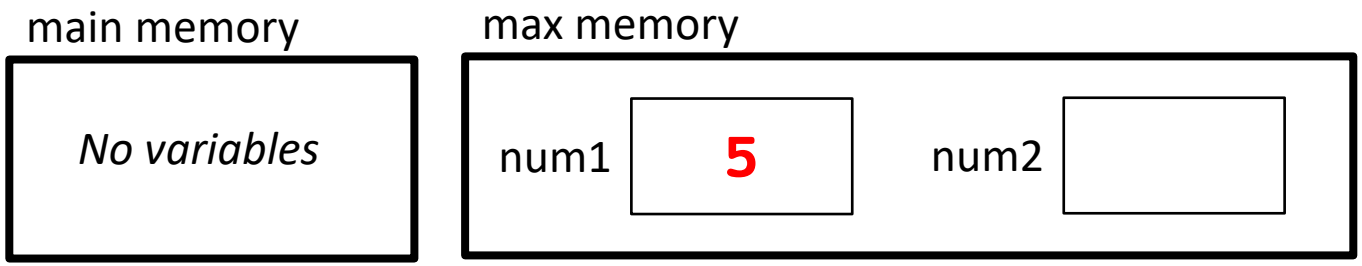
num1 num2

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```

Multiple Return Statements




```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory

No variables

max memory

num1 **5**

num2 **1**

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory

No variables

max memory

num1 | 5 | num2 | 1

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2


def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory

No variables

max memory

num1 | 5 | num2 | 1

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory

No variables

max memory

num1 | 5 | num2 | 1

```
def max(num1, num2):
    if num1 >= num2:
        return num1    5

    return num2


def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory

No variables

max memory

num1 | 5 | num2 | 1

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2


def main():
    larger = max(5, 1)
```

5

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory

No variables

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2


def main():
    larger = max(5, 1)
```

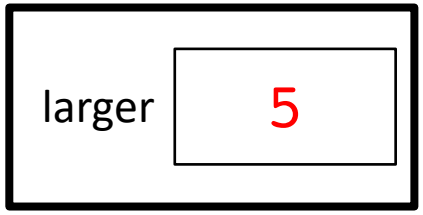
5

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory




```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(5, 1)
```

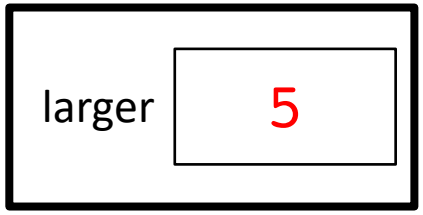
5

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

main memory




```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(5, 1)
```

terminal

```
> python3 maxmax.py
```

Multiple Return Statements

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2


def main():
    larger = max(5, 1)
```


Multiple Return Statements

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2


def main():
    larger = max(1, 5)
```


Multiple Return Statements

main memory

No variables

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2
```

```
def main():
    larger = max(1, 5)
```

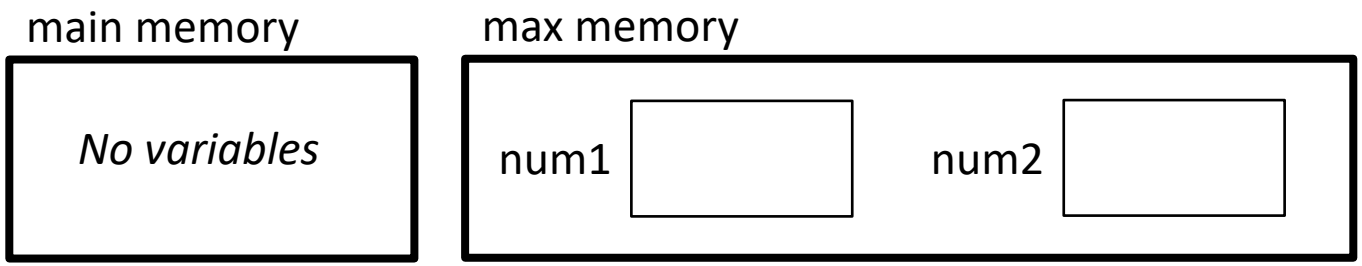

Multiple Return Statements

main memory

No variables

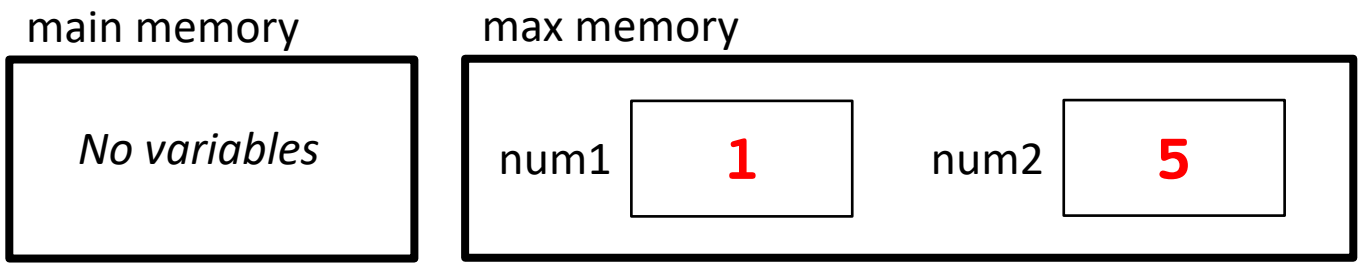
```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(1, 5)
```


Multiple Return Statements



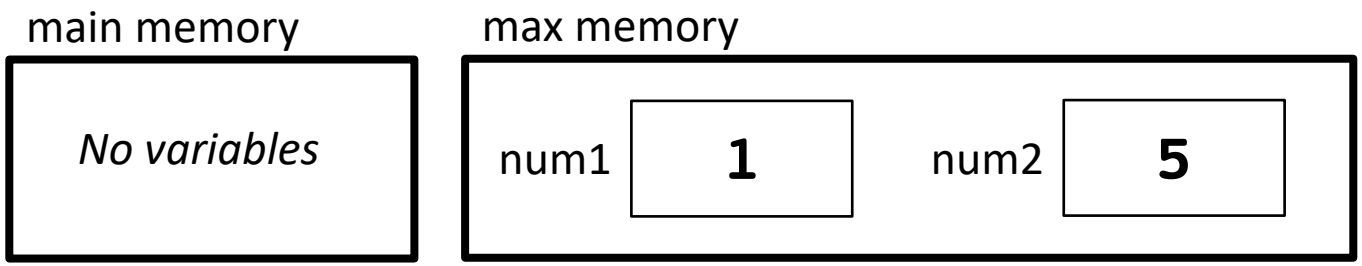

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(1, 5)
```

Multiple Return Statements



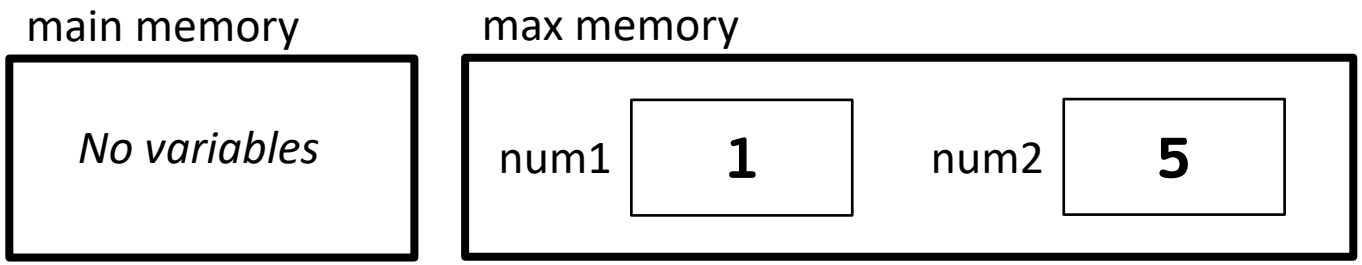

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(1, 5)
```

Multiple Return Statements




```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2


def main():
    larger = max(1, 5)
```

Multiple Return Statements




```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2
```

5

```
def main():
    larger = max(1, 5)
```

Multiple Return Statements

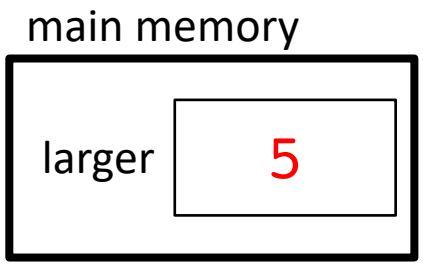
main memory

No variables

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2


def main():
    larger = max(1, 5)
```

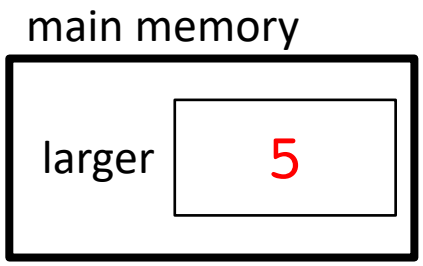
5

Multiple Return Statements




```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():          5
    larger = max(1, 5)
```

Multiple Return Statements



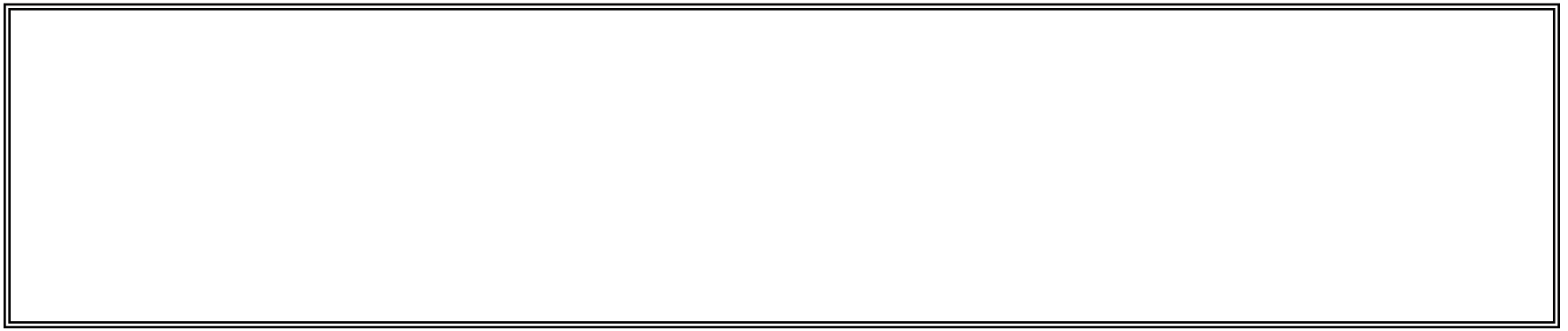

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2



def main():
    larger = max(1, 5)
```

Lecture Plan

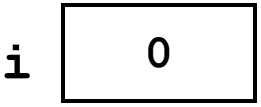
- Functions: From Karel to Python
- **Example: Factorial**
- More About Functions
- **Example**: Graphics

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

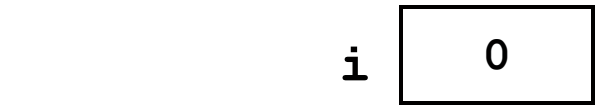
i 



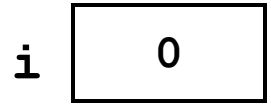
```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```



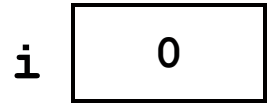
```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```



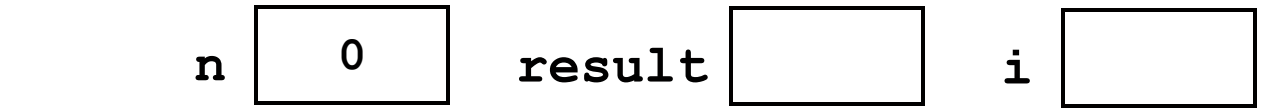
```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```



```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```



```
def factorial(n):
    result = 1
    for i in range(n):
        result *= (i + 1)

    return result
```



```
def factorial(n):
    result = 1
    for i in range(n):
        result *= (i + 1)

    return result
```

n | 0 | result | 1 | i |

```
def factorial(n):
    result = 1
    for i in range(n):
        result *= (i + 1)

    return result
```

n	0	result	1	i	0

```
def factorial(n):
    result = 1
    for i in range(n):
        result *= (i + 1)

    return result
```

n 0 result 1 i 0

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

1

i 0

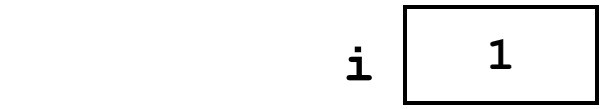
```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

1

i | 0

```
0   1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```



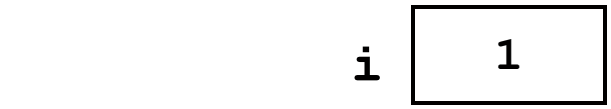

```
0    1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i | 1

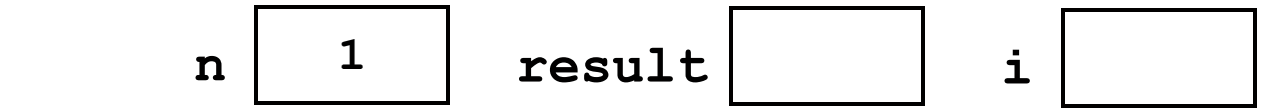
```
0    1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```




```
0    1
```

```
def factorial(n):
    result = 1
    for i in range(n):
        result *= (i + 1)

    return result
```




```
0    1
```

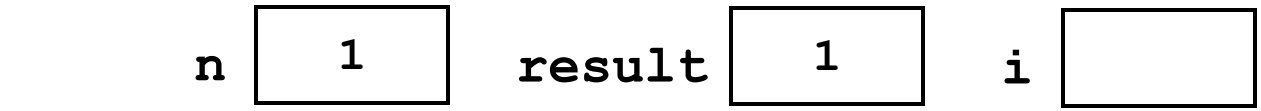
Parameters

Every time a function is called, new memory is created for that call.

Parameter values are passed in.

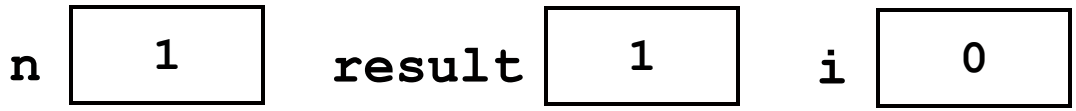
All *local* variables start fresh (no old values)

```
def factorial(n):
    result = 1
    for i in range(n):
        result *= (i + 1)

    return result
```



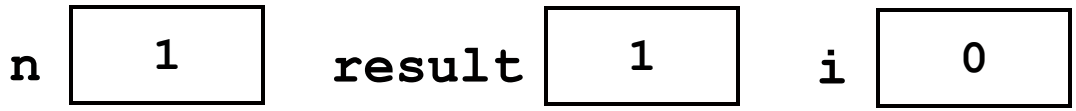

```
0    1
```

```
def factorial(n):
    result = 1
    for i in range(n):
        result *= (i + 1)

    return result
```



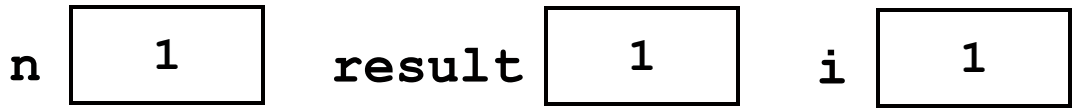

```
0    1
```

```
def factorial(n):
    result = 1
    for i in range(n):
        result *= (i + 1)

    return result
```




```
0    1
```

```
def factorial(n):
    result = 1
    for i in range(n):
        result *= (i + 1)

    return result
```




```
0    1
```

```
def factorial(n):
    result = 1
    for i in range(n):
        result *= (i + 1)

    return result
```

n 1 result 1 i 1

```
0    1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

1

i 1

```
0    1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

1

i 1

```
0     1
1     1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i | 2

```
0     1
1     1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i | 2

```
0     1
1     1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i | 2

```
0     1
1     1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i | 2

```
0     1
1     1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

2

i 2

```
0     1
1     1
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

2

i 2

```
0     1
1     1
2     2
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i 3

```
0    1
1    1
2    2
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i | 3

```
0    1
1    1
2    2
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i 3

```
0    1
1    1
2    2
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i 3

```
0    1
1    1
2    2
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

6

i 3

```
0    1
1    1
2    2
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

6

i 3

```
0     1
1     1
2     2
3     6
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i 4

```
0    1
1    1
2    2
3    6
```

```
def main():
    for i in range(MAX_NUM):
        print(i, factorial(i))
```

i | 4

```
0    1
1    1
2    2
3    6
```

Parameters

Every time a function is called, new memory is created for the call.

Lecture Plan

- Functions: From Karel to Python
- Example: Factorial
- **More About Functions**
- **Example**: Graphics

Bad Times With functions

```
// NOTE: This program is buggy!!

def add_five(x):
    x = x + 5



def main():
    x = 3
    add_five(x)
  print("x = " + x)
```

Bad Times With functions

If you change a parameter using =, the change does not persist outside the function!

Bad Times With functions

```
// NOTE: This program is buggy!!

def add_five(x):
    x = x + 5



def main():
    x = 3
    add_five(x)
  print("x = " + x)
```

Good Times With functions

```
// NOTE: This program is feeling just fine...

def add_five(x):
    x = x + 5
  return x


def main():
    x = 3
    x = add_five(x)
  print("x = " + x)
```


More Examples

Changed Name

```
def main():
    num = 5
    cow(num)


def cow(grass):
    print(grass)
```


Same Variable Name

```
def main():
    num = 5
    cow()
    print(num)


def cow():
    num = 10
    print(num)
```


No functions in functions

```
def main():
    print("hello world")
    def say_goodbye():
        print("goodbye!")
```

Technically legal, but often a sign at the start that you are confusing definition and calling

No functions in functions

```
def main():
    print("hello world")
    say_goodbye()


def say_goodbye():
    print("goodbye!")
```

Remember Booleans?

Boolean Variable

```
karel_is_awesome = True

my_bool = 1 < 2
```


Is Even

```
def main():
    for i in range(100):
        if is_even(i):
            print(i)
```


Boolean Return

```
def main():
    for i in range(100):
        if is_even(i):
            print(i)
```

```
def is_even(x):
    if x % 2 == 0:
        return True
    else:
        return False
```

Boolean Return

```
def main():
    for i in range(100):
        if is_even(i):
            print(i)
```

```
def is_even(x):
    return x % 2 == 0
```

Is Divisible By 7

```
def main():
    for i in range(100):
        if is_divisible_by(i, 7):
            print(i)
```


Boolean Return

```
def main():
    for i in range(100):
        if is_divisible_by(i, 7):
            print(i)
```

```
def is_divisible_by(num, divisor):
    if num % divisor == 0:
        return True
    else:
        return False
```

Boolean Return

```
def main():
    for i in range(100):
        if is_divisible_by(i, 7):
            print(i)



def is_divisible_by(num, divisor):
    return num % divisor == 0
```


Can a function return multiple values?

YES!

Multiple Return Values

```
def max(num1, num2):
    if num1 >= num2:
        return num1

    return num2
```

terminal

```
> python3 maxmax.py
5 is bigger.
```

```
def main():
    larger = max(5, 1)
    print(str(larger) + " is bigger.")
```


Multiple Return Values

```
def order(num1, num2):
    if num1 >= num2:
        return num1, num2

    return num2, num1
```

terminal

```
> python3 maxmax.py
1 is smaller than 5
```

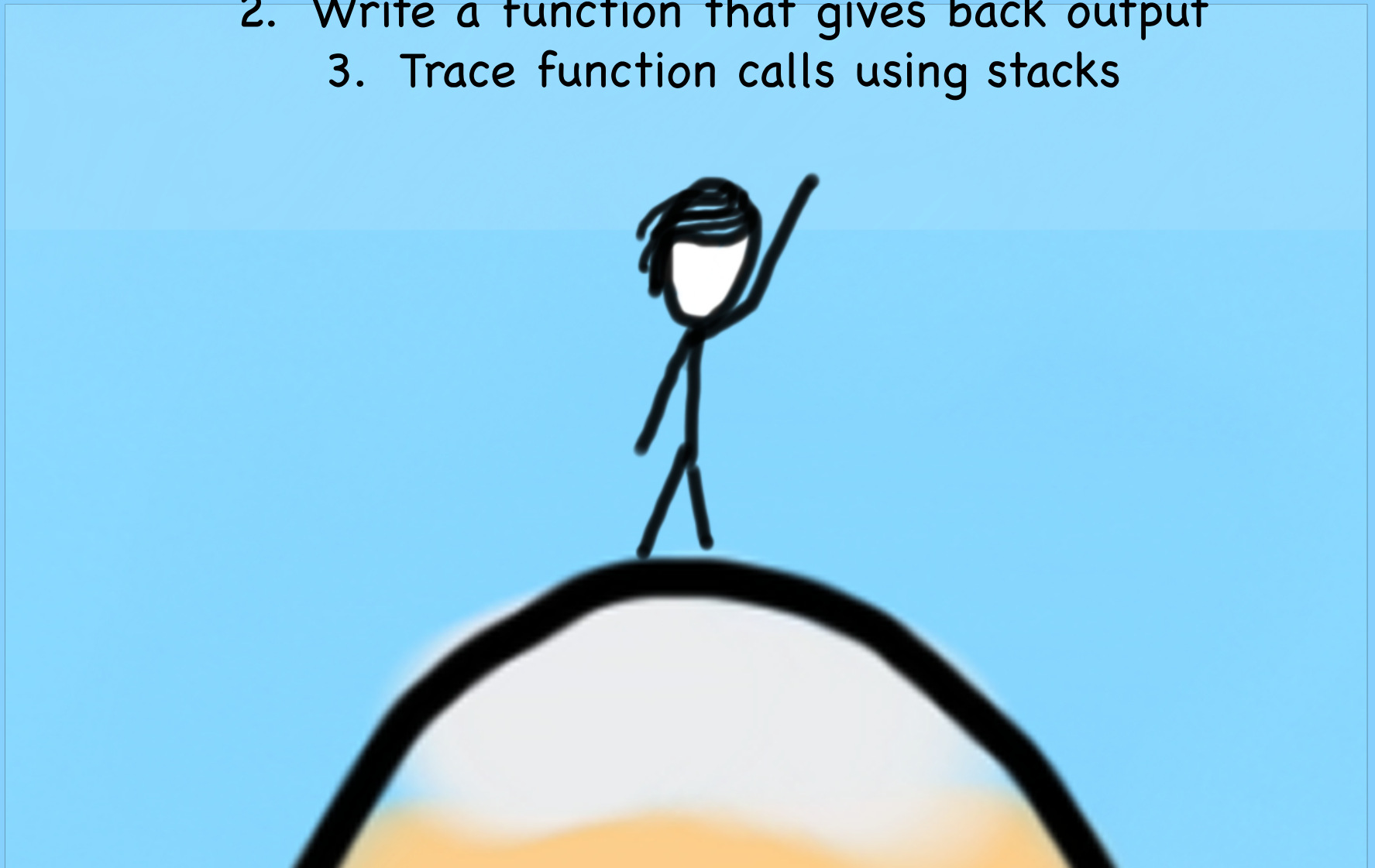
```
def main():
    smaller, larger = order(5, 1)
    print(str(smaller) + " is smaller than " + str(larger))
```

Lecture Plan

- Functions: From Karel to Python
- Example: Factorial
- More About Functions
- **Example: Graphics**

Learn How To:

1. Write a function that takes in input
2. Write a function that gives back output
3. Trace function calls using stacks



Bonus Exercise

- Greek mathematicians took a special interest in numbers that are equal to the sum of their proper divisors (a proper divisor of *n* is any divisor less than *n* itself). They called such numbers ***perfect numbers***. For example, 6 is a perfect number because it is the sum of 1, 2, and 3, which are the integers less than 6 that divide evenly into 6. Similarly, 28 is a perfect number because it is the sum of 1, 2, 4, 7, and 14.
- Design and implement a Python program that finds all the perfect numbers between two limits. For example, if the limits are 1 and 10000, the output should look like this: