Discussion 2

Environment Diagrams and Higher-Order Functions

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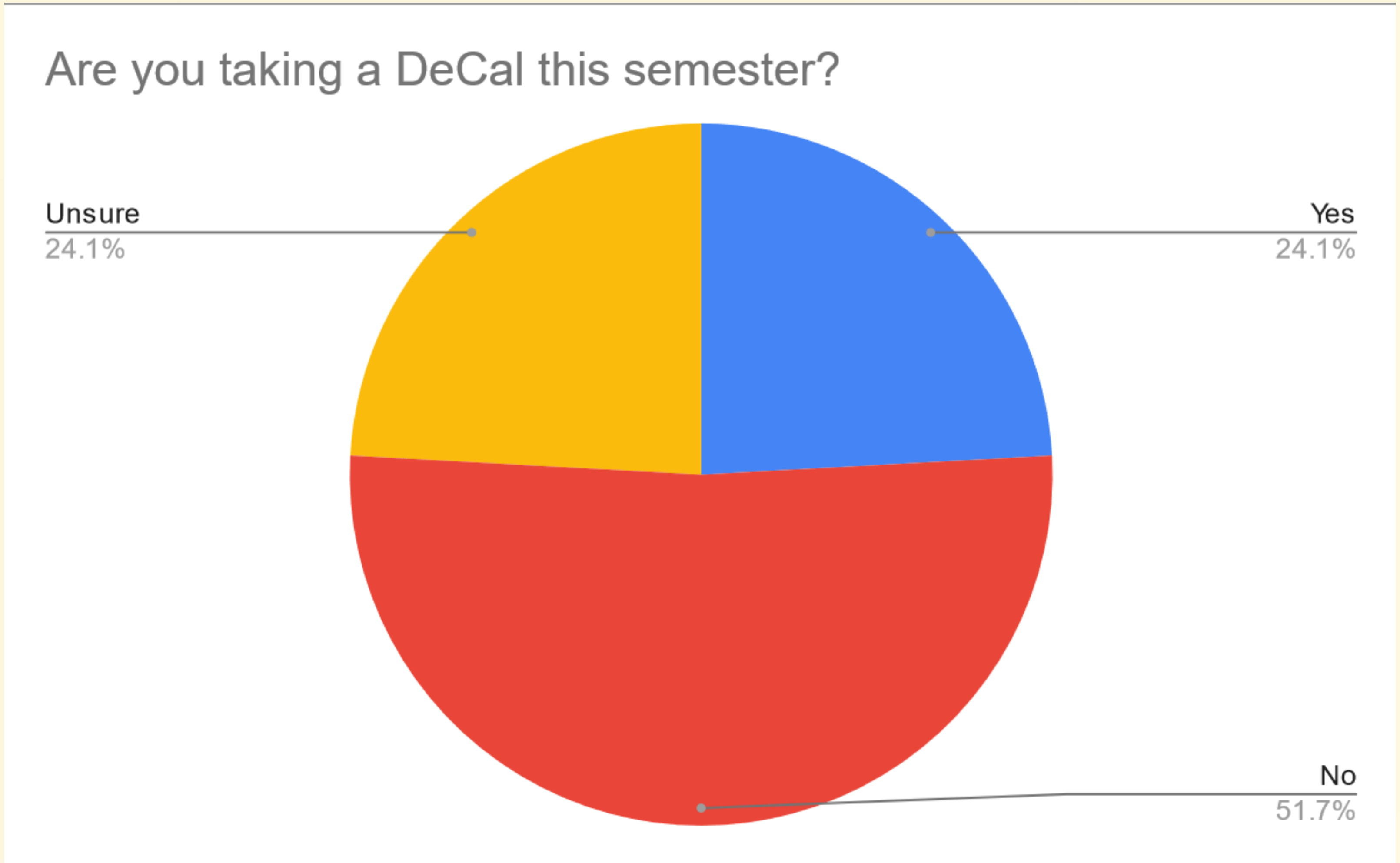
Announcements

- Hog
  - Due today!
- HW 2 released!
  - Due Thursday
- CSM Sections have opened
  - Small group tutoring sections (5-6 people), get to see more of the content
  - I joined a CSM section and found it incredibly useful! Would *highly* recommend
- Discussion videos exist! Walkthroughs for all problems 🥳

Results from last discussion



Questions and Comments from last section

- The general thing that I enjoy are things completely unrelated to the actual course itself partially because it doesn't take up time that could be done for going over discussion, but also because it's fun
- Environment Diagram practice problems
  - 👀 i wonder what this discussion covers 🤔
- HOFs
  - 👀 i wonder what this discussion covers 🤔
- Lambda examples and if we have time then currying is quite confusing.
  - 👀 i wonder what this discussion covers 🤔
- (Formerly) Waitlisted students:
  - You can get attendance credit for all discussions/labs you missed - just **email** me if you haven't already for which discussions/labs you've missed

Questions and Comments from last section

- Exam prep
  - Will be at the end of this discussion
- When you pass a string into a print statement, what is the type of the object that's printed? It's different from the return statement that displays a string object instead.
  - It's not actually any type! Think of it as `print` outputting something that's supposed to be 'human-readable', and `return` outputting something that's more 'machine-readable'
  - More on this later in the course
- Getting more help at Lab
  - Just keep your hand raised, we'll get to you 😭
  - Lab is also collaborative; there is no penalty for looking at other people's code!

Questions and Comments from last section

- Other questions
    - Check the solutions
    - (for environment diagrams in particular, use tutor.cs61a.org!)
    - During lab, feel free to collaborate on it! I know the lab room isn't the best for collaboration, but lab is meant to be a space where collaboration is very much allowed!

Temperature Check 🌡️

- Environment Diagrams
- `lambda` functions
- Higher-order Functions

All slides can be found on

`teaching.rouxl.es`

Environment Diagrams 🌎

Environment Diagrams

- Environment diagrams are a great way to learn how coding languages work under the hood
- Keeps track of all the variables that have been defined, and the values that they hold
    - Done with the use of *frames*
- Expressions evaluate to values:
    - `1 + 1` → `2`
- Statements do not evaluate to values:
    - `def` statements, assignments, etc.
- Statements change our environment

Frames

- The `Global Frame` exists by default
- Frames list bindings between variables and their values
- Frames also tell us how to look up values

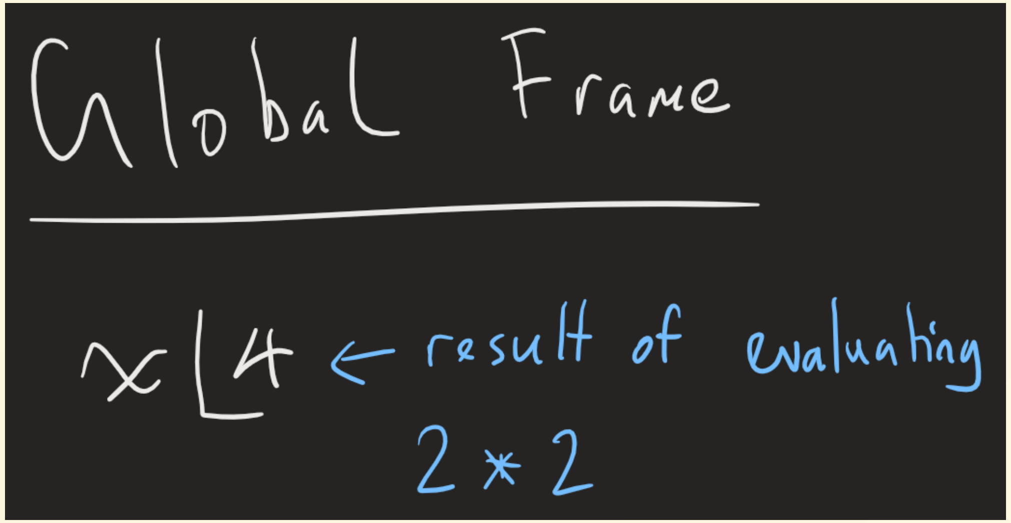
Assignment

- Assignment statements bind a value to a name
  - The right side is evaluated before being bounded to the name on the left
  - `=` is not the same in Python and mathematics
- These are then put in the *correct frame* in the environment diagram

```
x = 2 * 2 # 2 * 2 is evaluated before bound to the name x
```

Assignment

```
x = 2 * 2 # 2 * 2 is evaluated before bound to the name x
```



`def` statements

- Creates function (objects), and binds them to a variable name
- The function is **not** executed until called!
- Name of the variable is the name of the function
- Parent of the function is the frame where the function is *defined*
- Keep track of:
  - Name
  - Parameters
  - Parent

Example

```python
def square(x):
  return x * x
```

- Keep track of the name, parameters, and parent!
- Uses *pointers* (unlike for primitive values)

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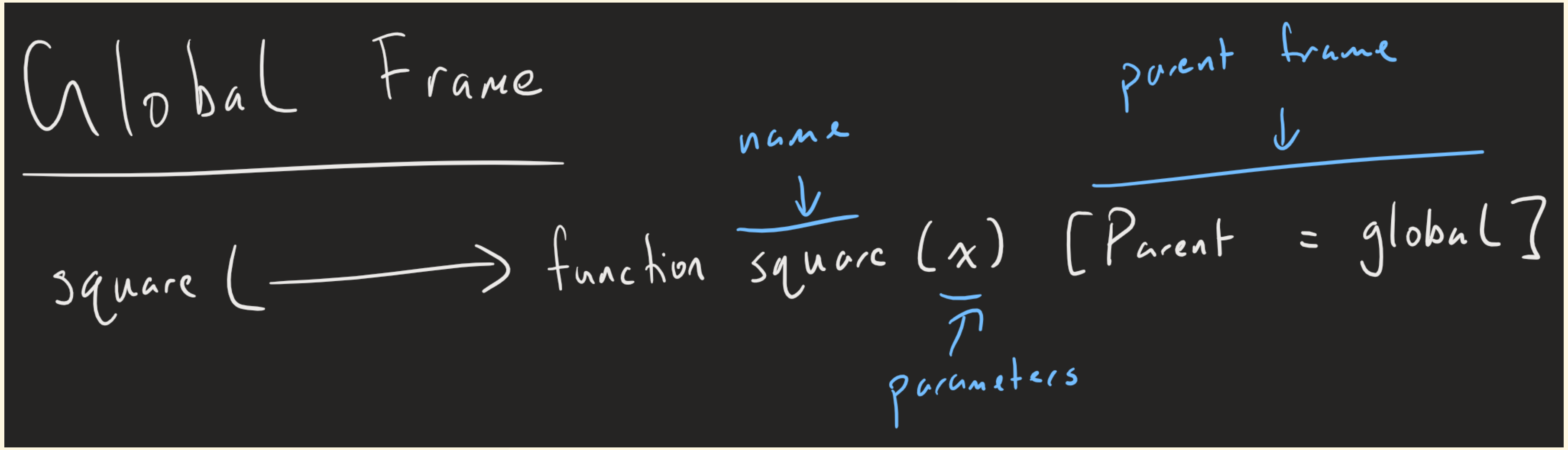


Call Expressions

(Order of operations for nested call expressions)

Example 1

```
add(5, 9) # 14
```

Example 2

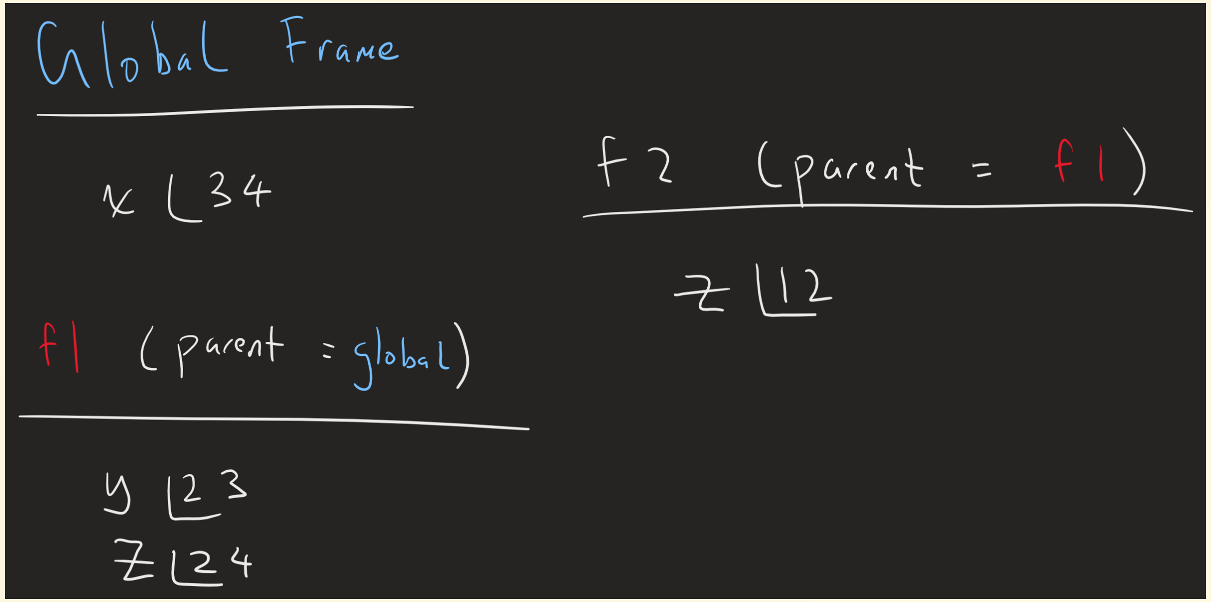
```
x = 3
add(2, add(x, 4)) # 9
```

Variable Lookup ☝️

- Look in your current frame to find your variable
- If it doesn't exist, repeat the same process in the parent frame (including the lookup if you don't find anything)
- If you reach the global frame and still can't find anything, the program errors
    - This is because the variable doesn't exist 😭

Variable Lookup

Example



(Assume that we're looking for variables inside `f2`)

Variable Lookup

Example

Variable	Value
x	34
y	23
z	12

- If we start off in `f2`, we already see `z` in `f2`, so there is no need to look at the frame above.
- However, for the case of `y`, we do need to look up to its parent frame, and for `x`, we need to lookup 2 levels

New Frames

- Label your frame with a unique index (convention is `f1`, `f2`, etc.)
- Write down the name of the function object
  - Not necessarily the name of the variable!
- Write down the parent that the function you're calling has
- Separately, all frames (other than the global frame) have a return value
  - This can be `None` if nothing is specified

Example

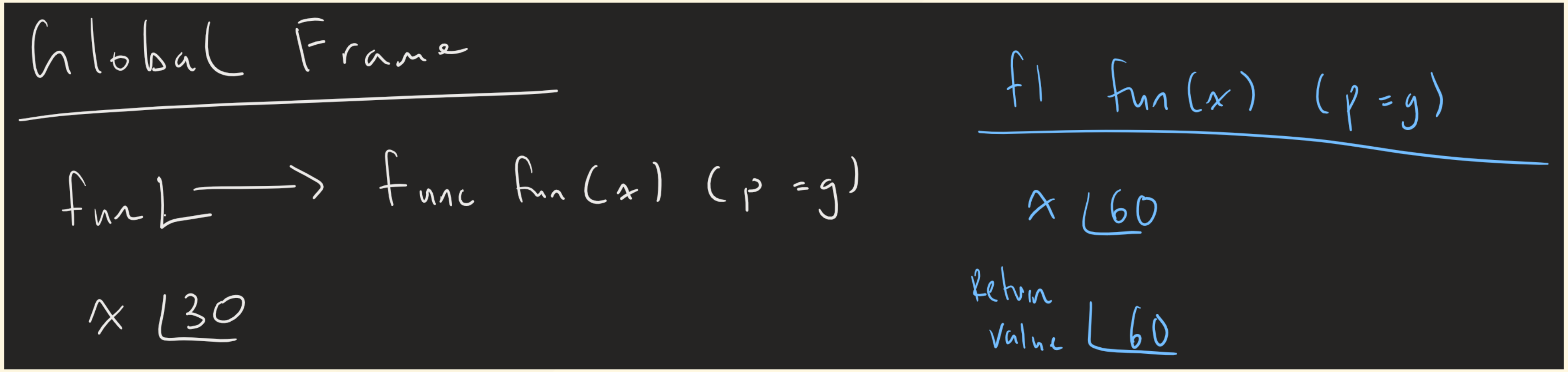
```
def fun(x):
  x = x * 2
  return x

x = 30
fun(x)
```

Example

```python
def fun(x):
  x = x * 2
  return x

x = 30
fun(x)
```



Question 1

Draw the environment diagram for the following

```python
def double(x):
    return x * 2

hmmm = double
wow = double(3)
hmmm(wow)
```

Attendance

`links.rouxl.es/disc`

Question 2 (Walkthrough)

```python
def f(x):
    return x

def g(x, y):
    if x(y):
        return not y
    return y

x = 3
x = g(f, x)
f = g(f, 0)
```

`lambda` Functions and Higher-Order Functions

- A `lambda` expression evaluates to a `lambda` function
  - Can be used as the operator for a function!
- These functions work the same way as a normal function
  - Can be written in 1 line - faster way to make functions
  - Similar to `def` in usage, but different syntax
- `lambda`s are especially useful when you want to use a function once and then never use it again (will see examples of this)

`lambda` Syntax

- `lambda <args>: <body>`
- What goes in `<body>` must be a single expression

`lambda` Example

```python
def func(x, y):
  return x + y

func = lambda x, y: x + y
# Notice how I have to do the binding to a variable myself
```

```python
def i(j, k, l):
  return j * k * l

i = lambda j, k, l: j * k * l
```

`lambda` Example 2

`lambda` functions can also be used as the operator for a function!

```python
(lambda x, y: x + y)(2, 3) # 5

# Equivalent to

def add(x, y):
  return x + y

add(2, 3) # 5
```

Higher Order Functions (HOF)

- HOFs are functions that can do the following things (can be both):
  1. Take in other functions as inputs
  2. Return a function as an output
- You can treat a function as just an object or a value (there's nothing special about them)
- `function` and `function()` mean different things!
  - `function` refers to the object itself (in the environment diagram, it refers to what the arrow is pointing to)
  - `function()` actually calls and executes the body of the function

HOF Example 1 (Functions as input)

```python
def double(x):
  return x * 2

def square(x):
  return x ** 2

def double_adder(f, x):
  return f(x) + f(x)

double_adder(double, 3) # 12
double_adder(square, 3) # 18
# Passed in two different functions
```

HOF Example 2 (Functions as output)

```
def f(x):
  def g(y):
    return x + y
  return g

a = f(2)
a(3) # 5

# Same thing as calling f(2)(3)
```

HOF Example 2

```python
def f(x):
  def g(y):
    def h(z):
      return x + y + z
    return h
  return g

lambda x: lambda y: lambda z: x + y + z
```

The two above are equivalent statements!

(Notice how the lambda one takes up far less space!)

Worksheet!

Currying

Currying is one application of the HOFs from earlier.

```
lambda x: lambda y: x + y
```

Instead of just any expression on the inside (for example `x + y`), we use a function!

```
def pow(x, y):
  x ** y

def curried_pow(x):
  def f(y):
    return pow(x, y)
  return f

curried_pow(3)(2)
# is the same as
pow(3, 2)
# You will need as many inner functions as you have arguments
```

Currying

- Currying is the process of turning a function that takes in *multiple* arguments to one that takes in *one* argument.
- What's the point?
  - Sometimes functions with 1 argument are far easier to deal with
  - Can create a bunch of functions that have slightly different starting values which saves on repeating code
  - Useful for the `map` function (it requires functions that have only 1 argument)
- Kind of hard to see the benefits until you write production code

Worksheet!

Mental Health Resources

- CAPS:
  - If you need to talk to a professional, please call CAPS at 510-642-9494.
- After Hours Assistance
  - For any assistance after hours, details on what to do can be found at this link

Anonymous Feedback Form

`links.rouxl.es/feedback`

Thanks for coming! 🥳

Please give me feedback on what to improve!