Function Examples
Class outline:

- Currying
- Decorators
- Review
Currying
(Reminder) Function currying

**Currying**: Converting a function that takes multiple arguments into a single-argument higher-order function.

A function that currys any two-argument function:

```python
def curry2(f):
    def g(x):
        def h(y):
            return f(x, y)
        return h
    return g
```

```python
from operator import add
make_adder = curry2(add)
make_adder(2)(3)
```

```python
curry2 = lambda f: lambda x: lambda y: f(x, y)
```
Use case for currying #1

Whenever another function requires a function that only takes one argument:

```python
def transform_numbers(num1, num2, num3, transform):
    return transform(num1), transform(num2), transform(num3)
```

```python
transform_numbers(3, 4, 5, curry2(add)(60))
```
Use case for currying #1

Whenever another function requires a function that only takes one argument:

```python
def transform_numbers(num1, num2, num3, transform):
    return transform(num1), transform(num2), transform(num3)
```

```python
transform_numbers(3, 4, 5, curry2(add)(60))
```

Alternate approach:

```python
transform_numbers(3, 4, 5, lambda x: add(60, x))
```
Use case for currying #2

Turning a generalized function into a specialized function:

```python
def html_tag(tag_name, text):
    return "<" + tag_name + "">" + text + "</" + tag_name + ">

p_tag = curry2(html_tag)("p")
p_tag("hello hello")
```
Use case for currying #2

Turning a generalized function into a specialized function:

```python
def html_tag(tag_name, text):
    return "<" + tag_name + ">" + text + "</" + tag_name + ">"

p_tag = curry2(html_tag)("p")
p_tag("hello hello")
```

Alternate approach:

```python
import functools

p_tag = functools.partial(html_tag, "p")
p_tag("hello hello")
```
Why learn currying in Python?

It's good for you!

CS61A introduces many concepts that aren't standard Python practice, but that show up in other languages.

Currying is a very common practice in functional programming languages like Haskell or Clojure.
Decorators
A tracing function

Let's make a higher-order tracing function.

def trace1(f):
    """Return a function that takes a single argument, x, prints it, computes and prints F(x), and returns the computed value.
    >>> square = lambda x: x * x
    >>> trace1(square)(3)
    \- 3
    <- 9
    9
    """
def \texttt{trace1}(f):
    
    
    
    
    
    
    """Return a function that takes a single argument, x, prints it, computes and prints F(x), and returns the computed value."

    >>> square = \texttt{lambda} \texttt{x: x} \ast \texttt{x}
    >>> \texttt{trace1(square)}(3)
    
    -> 3
    <- 9
    9
    ""

    
    
    
    
    
    
    
    
    
    
    
    """

    def \texttt{traced}(x):
        print("->", x)
        r = f(x)
        print("<-", r)
        \texttt{return} r
    
    \texttt{return} \texttt{traced}
A tracing decorator

What if we always wanted a function to be traced?

```python
@trace1
def square(x):
    return x * x
```

That's equivalent to..

```python
def square(x):
    return x * x
square = trace1(square)
```
General decorator syntax

The notation:

```python
@ATTR
def aFunc(...):
    ...
```

is essentially equivalent to:

```python
def aFunc(...):
    ...
    aFunc = ATTR(aFunc)
```

**ATTR** can be any expression, not just a single function name.
Review
What Would Python Do? #1

WWPD exercises test our understanding of how Python evaluates code and what it chooses to display in the shell.

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>print(5)</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>print(print(5))</code></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What Would Python Do? #1

WWPD exercises test our understanding of how Python evaluates code and what it chooses to display in the shell.

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>print(5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>print(print(5))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What Would Python Do? #1

WWPD exercises test our understanding of how Python evaluates code and what it chooses to display in the shell.

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>print(5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>print(print(5))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What Would Python Do? #1

WWPD exercises test our understanding of how Python evaluates code and what it chooses to display in the shell.

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><code>print(5)</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>print(print(5))</code></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

```
>> 5
5
```
What Would Python Do? #1

WWPD exercises test our understanding of how Python evaluates code and what it chooses to display in the shell.

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>print(5)</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>print(print(5))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

```python
>> 5
5
```
What Would Python Do? #1

WWPD exercises test our understanding of how Python evaluates code and what it chooses to display in the shell.

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>print(5)</td>
<td>None</td>
<td>5</td>
</tr>
<tr>
<td>print(print(5))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

```bash
>> 5
5
```
## What Would Python Do? #1

WWPD exercises test our understanding of how Python evaluates code and what it chooses to display in the shell.

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><code>print(5)</code></td>
<td>None</td>
<td>5</td>
</tr>
<tr>
<td><code>print(print(5))</code></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

```python
>>> 5
5
>>> print(5)
5
```
What Would Python Do? #1

WWPD exercises test our understanding of how Python evaluates code and what it chooses to display in the shell.

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>print(5)</td>
<td>None</td>
<td>5</td>
</tr>
<tr>
<td>print(print(5))</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

```python
>>> 5
5
>>> print(5)
5
```
What Would Python Do? #1

WWPD exercises test our understanding of how Python evaluates code and what it chooses to display in the shell.

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>print(5)</td>
<td>None</td>
<td>5</td>
</tr>
<tr>
<td>print(print(5))</td>
<td>None</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>

```python
>>> 5
5
>>> print(5)
5
```
What Would Python Do? #1

WWPD exercises test our understanding of how Python evaluates code and what it chooses to display in the shell.

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>print(5)</td>
<td>None</td>
<td>5</td>
</tr>
<tr>
<td>print(print(5))</td>
<td>None</td>
<td>5</td>
</tr>
</tbody>
</table>

```>
5
5
>>> print(5)
5
>>> print(print(5))
5
None```
What Would Python Do? #2

```python
def delay(arg):
    print('delayed')
    def g():
        return arg
    return g
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>delay(6)()</td>
<td></td>
<td></td>
</tr>
<tr>
<td>delay(delay)()(6)()</td>
<td></td>
<td></td>
</tr>
<tr>
<td>print(delay(print)()(4))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What Would Python Do? #2

```python
def delay(arg):
    print('delayed')

def g():
    return arg
return g
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>delay(6)()</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>delay(delay)()(6)()</td>
<td></td>
<td></td>
</tr>
<tr>
<td>print(delay(print)()())(4))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What Would Python Do? #2

```python
def delay(arg):
    print('delayed')

def g():
    return arg
return g
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>delay(6)()</code></td>
<td>6</td>
<td><code>delayed</code></td>
</tr>
<tr>
<td><code>delay(delay)()(6)</code></td>
<td>6</td>
<td><code>delayed</code></td>
</tr>
<tr>
<td><code>print(delay(print)()(4))</code></td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>
What Would Python Do? #2

```python
def delay(arg):
    print('delayed')

def g():
    return arg
return g
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>delay(6)()</td>
<td>6</td>
<td>delayed 6</td>
</tr>
<tr>
<td>delay(delay)()(6)()</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>print(delay(print)()(4))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What Would Python Do? #2

```python
def delay(arg):
    print('delayed')

def g():
    return arg
return g
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>delay(6)()</td>
<td>6</td>
<td>delayed 6</td>
</tr>
<tr>
<td>delay(delay)()(6)()</td>
<td>6</td>
<td>delayed delayed 6</td>
</tr>
<tr>
<td>print(delay(print)()(4))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What Would Python Do? #2

def delay(arg):
    print('delayed')
    def g():
        return arg
    return g

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>delay(6)()</td>
<td>6</td>
<td>delayed 6</td>
</tr>
<tr>
<td>delay(delay)()(6)()</td>
<td>6</td>
<td>delayed delayed 6</td>
</tr>
<tr>
<td>print(delay(print)()())(4))</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>
def delay(arg):
    print('delayed')

def g():
    return arg
return g

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>delay(6)()</td>
<td>6</td>
<td>delayed 6</td>
</tr>
<tr>
<td>delay(delay)()(6)()()</td>
<td>6</td>
<td>delayed delayed 6</td>
</tr>
<tr>
<td>print(delay(print)()(4))</td>
<td>None</td>
<td>delayed 4 None</td>
</tr>
</tbody>
</table>
What Would Python Do? #3

```python
def pirate(arggg):
    print('matey')
    def plunder(arggg):
        return arggg
    return plunder

The expression | Evaluates to | Interactive output
--- | --- | ---
pirate('treasure')('scurvy') | | |
add(pirate(3)(square)(4), 1) | | |
pirate(pirate(pirate))(5)(7) | | |
```

A name evaluates to the value bound to that name in the earliest frame of the current environment in which that name is found.
# What Would Python Do? #3

```python
def pirate(arggg):
    print('matey')
    def plunder(arggg):
        return arggg
    return plunder

def plunder(arggg):
    return arggg
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>pirate('treasure')('scurvy')</code></td>
<td>'scurvy'</td>
<td></td>
</tr>
<tr>
<td><code>add(pirate(3)(square)(4), 1)</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>pirate(pirate(pirate))(5)(7)</code></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A name evaluates to the value bound to that name in the earliest frame of the current environment in which that name is found.
What Would Python Do? #3

```python
def pirate(arggg):
    print('matey')
    def plunder(arggg):
        return arggg
    return plunder
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>pirate('treasure')('scurvy')</code></td>
<td>'scurvy'</td>
<td>matey 'scurvy'</td>
</tr>
<tr>
<td><code>add(pirate(3)(square)(4), 1)</code></td>
<td></td>
<td></td>
</tr>
<tr>
<td><code>pirate(pirate(pirate))(5)(7)</code></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A name evaluates to the value bound to that name in the earliest frame of the current environment in which that name is found.
What Would Python Do? #3

```python
def pirate(arggg):
    print('matey')

def plunder(arggg):
    return arggg

return plunder
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>pirate('treasure')('scurvy')</code></td>
<td>'scurvy'</td>
<td>matey 'scurvy'</td>
</tr>
<tr>
<td><code>add(pirate(3)(square)(4), 1)</code></td>
<td>17</td>
<td></td>
</tr>
<tr>
<td><code>pirate(pirate(pirate))(5)(7)</code></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A name evaluates to the value bound to that name in the earliest frame of the current environment in which that name is found.
What Would Python Do? #3

```python
def pirate(arggg):
    print('matey')

def plunder(arggg):
    return arggg
return plunder
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>pirate('treasure')('scurvy')</td>
<td>'scurvy'</td>
<td>matey</td>
</tr>
<tr>
<td></td>
<td></td>
<td>'scurvy'</td>
</tr>
<tr>
<td>add(pirate(3)(square)(4), 1)</td>
<td>17</td>
<td>matey</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>pirate(pirate(pirate))(5)(7)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A name evaluates to the value bound to that name in the earliest frame of the current environment in which that name is found.
What Would Python Do? #3

```python
def pirate(arggg):
    print('matey')
    def plunder(arggg):
        return arggg
    return plunder
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>pirate('treasure')('scurvy')</code></td>
<td>'scurvy'</td>
<td>matey 'scurvy'</td>
</tr>
<tr>
<td><code>add(pirate(3)(square)(4), 1)</code></td>
<td>17</td>
<td>matey 17</td>
</tr>
<tr>
<td><code>pirate(pirate(pirate))(5)(7)</code></td>
<td>Error</td>
<td></td>
</tr>
</tbody>
</table>

A name evaluates to the value bound to that name in the earliest frame of the current environment in which that name is found.
What Would Python Do? #3

```python
def pirate(arggg):
    print('matey')

def plunder(arggg):
    return arggg

return plunder
```

<table>
<thead>
<tr>
<th>The expression</th>
<th>Evaluates to</th>
<th>Interactive output</th>
</tr>
</thead>
<tbody>
<tr>
<td>pirate('treasure')('scurvy')</td>
<td>'scurvy'</td>
<td>matey 'scurvy'</td>
</tr>
<tr>
<td>add(pirate(3)(square)(4), 1)</td>
<td>17</td>
<td>matey 17</td>
</tr>
<tr>
<td>pirate(pirate(pirate))(5)(7)</td>
<td>Error</td>
<td>matey Error</td>
</tr>
</tbody>
</table>

A name evaluates to the value bound to that name in the earliest frame of the current environment in which that name is found.
```python
def horse(mask):
    horse = mask
    def mask(horse):
        return horse
        return horse(mask)

mask = lambda horse: horse(2)
horse(mask)
```

**Global frame**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>horse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mask</td>
</tr>
</tbody>
</table>

**f1:**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Return value</td>
</tr>
</tbody>
</table>

**f2:**


Return value

\( f_3: \)

\[
\begin{align*}
\text{Return value} & \\
\end{align*}
\]
def remove(n, digit):
    """Return digits of non-negative N that are not DIGIT, for some non-negative DIGIT less than 10.
    >>> remove(231, 3)
    21
    >>> remove(243132, 2)
    4313
    """
kept = 0
digits = 0
while ____________________________:
    last = n % 10
    n = n // 10
    if ____________________________:
        kept = ____________________
        digits = ________________
return __________________________
def remove(n, digit):
    """Return digits of non-negative N
    that are not DIGIT, for some
    non-negative DIGIT less than 10.
    >>> remove(231, 3)
    21
    >>> remove(243132, 2)
    4313
    """
    kept = 0
    digits = 0
    while __________________________:
        last = n % 10
        n = n // 10
        if __________________________:
            kept = ____________________
            digits = _________________
    return __________________________
Implementing a function

```python
def remove(n, digit):
    """Return digits of non-negative N that are not DIGIT, for some non-negative DIGIT less than 10.
    >>> remove(231, 3)
    21
    >>> remove(243132, 2)
    4313
    """
    kept = 0
digits = 0
    while ____________________________:
        last = n % 10
        n = n // 10
        if ____________________________:
            kept = _____________________
            digits = ___________________
    return _________________________
```

- Read the description
- Verify the examples & pick a simple one
Implementing a function

def remove(n, digit):
    """Return digits of non-negative N that are not DIGIT, for some
    non-negative DIGIT less than 10.
    >>> remove(231, 3)
    21
    >>> remove(243132, 2)
    4313
    ""
    kept = 0
digits = 0
    while __________________________:
        last = n % 10
        n = n // 10
        if __________________________:
            kept = _________________
            digits = _______________
    return ___________________________

• Read the description
• Verify the examples & pick a simple one
• Read the template
def remove(n, digit):
    """Return digits of non-negative N that are not DIGIT, for some non-negative DIGIT less than 10.
    >>> remove(231, 3)
    21
    >>> remove(243132, 2)
    4313
    """
    kept = 0
digits = 0
    while 1:
        last = n % 10
        n = n // 10
        if 1:
            kept =
digits =
    return

- Read the description
- Verify the examples & pick a simple one
- Read the template
- Implement without the template, then change your implementation to match the template.
OR If the template is helpful, use it.
def remove(n, digit):
    """Return digits of non-negative N that are not DIGIT, for some non-negative DIGIT less than 10.
    >>> remove(231, 3)
    21
    >>> remove(243132, 2)
    4313
    """
    kept = 0
digits = 0
    while ________________________:
        last = n % 10
        n = n // 10
        if ________________________:
            kept = _________________
            digits = _______________
    return _______________________

• Read the description
• Verify the examples & pick a simple one
• Read the template
• Implement without the template, then change your implementation to match the template.
  OR If the template is helpful, use it.
• Annotate names with values from your chosen example
Implementing a function

def remove(n, digit):
    """Return digits of non-negative N that are not DIGIT, for some non-negative DIGIT less than 10.
    >>> remove(231, 3)
    21
    >>> remove(243132, 2)
    4313
    """
    kept = 0
digits = 0
while ____________________________:
    last = n % 10
    n = n // 10
    if ____________________________:
        kept = ____________________
        digits = ____________________
return ____________________________

- Read the description
- Verify the examples & pick a simple one
- Read the template
- Implement without the template, then change your implementation to match the template. OR If the template is helpful, use it.
- Annotate names with values from your chosen example
- Write code to compute the result
def remove(n, digit):
    """Return digits of non-negative N that are not DIGIT, for some non-negative DIGIT less than 10.
    >>> remove(231, 3)
    21
    >>> remove(243132, 2)
    4313
    ""
    kept = 0
digits = 0
while ______________________________:
    last = n % 10
    n = n // 10
    if ______________________________:
        kept = ______________________
        digits = ______________________
    return ____________________________

- Read the description
- Verify the examples & pick a simple one
- Read the template
- Implement without the template, then change your implementation to match the template.
  OR If the template is helpful, use it.
- Annotate names with values from your chosen example
- Write code to compute the result
- Did you really return the right thing?
def remove(n, digit):
    """Return digits of non-negative N that are not DIGIT, for some non-negative DIGIT less than 10.
    >>> remove(231, 3)
    21
    >>> remove(243132, 2)
    4313
    ""
    kept = 0
digits = 0
while ____________________________:
    last = n % 10
    n = n // 10
    if ____________________________:
        kept = __________________
        digits = ________________
return ____________________________

• Read the description
• Verify the examples & pick a simple one
• Read the template
• Implement without the template, then change your implementation to match the template.
  OR If the template is helpful, use it.
• Annotate names with values from your chosen example
• Write code to compute the result
• Did you really return the right thing?
• Check your solution with the other examples
def remove(n, digit):
    
    """Return digits of non-negative N that are not DIGIT, for some non-negative DIGIT less than 10.
    >>> remove(231, 3)
    21
    >>> remove(243132, 2)
    4313
    """
    kept = 0
digits = 0
while n > 0:
    last = n % 10
    n = n // 10
    if last != digit:
        kept = kept + (last * 10 ** digits)
        digits = digits + 1
return kept