Scheme

Announcements

The Scheme Programming Language

Expressions

An expression is evaluated in an environment (that gives symbols meaning) to produce a value.

Local frame: "the course instructor" has a specific meaning for a particular course.

Global frame: "multiply" is an operation that everyone knows about.

Local before Global: in a particular context, "multiply" can mean something different.

Scheme programs consist of expressions, which can be:

- Self-evaluating expressions: `2` `3.3` `true`
- Symbols: `+` `-` `quotient` `not`
- Call expressions: `(quotient 10 2)` `(f x)`
- Special forms: `(if a b c)` `(let ((x 2)) (+ x 1))`

Primitive expressions

Combinations

(Demo)

https://code.cs61a.org/

Defining Functions/Procedures

No **return** in Scheme; the value of a call expression is the value of the **last** body expression of the procedure

```
>>> def sum_squares(x, y):
...     return x * x + y * y
```

```
scm> (define (sum-squares x y)
       (+ (* x x) (* y y)))
```

Instead of multiple return statements, Scheme uses nested conditional expressions.

```
>>> def fib(n):
...     if n == 0 or n == 1:
...         return n
...     else:
...         return fib(n - 2) + fib(n - 1)
```

```
scm> (define (fib n)
       (if (or (= n 0) (= n 1))
           n
           (+ (fib (- n 2)) (fib (- n 1)))))
```

Python vs Scheme: Call Expressions

A call expression in Scheme has the parentheses on the outside.

```
>>> def sum_squares(x, y):
...     return x * x + y * y
...
>>> sum_squares(3, 4)
25
```

```
scm> (define (sum-squares x y)
       (+ (* x x) (* y y)))
sum-squares
scm> (sum-squares 3 4)
25
```

Some Scheme combinations are **not** call expressions because they are special forms.

```
>>> def f(x):
...     print(x)
...     return False
...
>>> f(3) and f(4)
3
False
```

```
scm> (define (f x) (print x) #f)
f
scm> (and (f 3) (f 4))
3
#f
```

Python vs Scheme: Iteration

Scheme has no for/while statements, so recursion is required to iterate.

```
>>> def sum_first_n(n):
...     return sum(range(1, n + 1))
...
>>> def sum_first_n(n):
...     total = 0
...     for k in range(1, n + 1):
...         total += k
...     return total
...
>>> def sum_first_n(n):
...     k = 1
...     total = 0
...     while k <= n:
...         k, total = k + 1, total + k
...     return total
...
>>> sum_first_n(5)
15
```

```
scm> (define (sum-first-n n)
       (define (f k total)
         (if (> k n)
             total
             (f (+ k 1) (+ total k))))
       (f 1 0))
sum-first-n
scm> (sum-first-n 5)
15
```

Scheme Documentation

https://cs61a.org/articles/scheme-spec

https://cs61a.org/articles/scheme-builtins/

Writing Scheme

Example: A-Plus-Abs-B

a-plus-abs-b takes numbers a and b and returns a + abs(b) without calling abs.

```
def a_plus_abs_b(a, b):
    """Return a+abs(b), but without calling abs.

    >>> a_plus_abs_b(2, 3)
    5
    >>> a_plus_abs_b(2, -3)
    5
    >>> a_plus_abs_b(-1, 4)
    3
    >>> a_plus_abs_b(-1, -4)
    3
    """
    if b < 0:
        f = ____sub____
    else:
        f = ____add____
    return f(a, b)
```

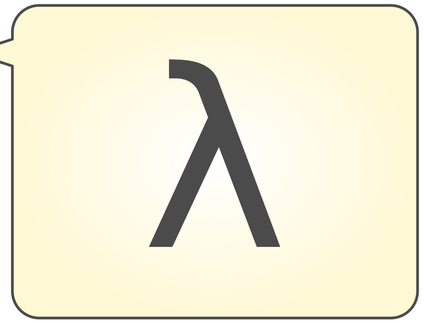
```
(define (a-plus-abs-b a b)
  ( ____(if (< b 0) - +)____ a b))
```

Lambda Expressions

Lambda Expressions

Lambda expressions evaluate to anonymous procedures

```
(lambda (<formal-parameters>) <body>)
```



Two equivalent expressions:

```
(define (plus4 x) (+ x 4))

(define plus4 (lambda (x) (+ x 4)))
```

An operator can be a call expression too:

```
((lambda (x y z) (+ x y (square z))) 1 2 3)
```

▶ 12

Evaluates to the $x+y+z^2$ procedure

What Would Scheme Do?

```
((lambda (g y) (g (g y))) (lambda (x) (+ x 1)) 3)

(define (f g)
  (lambda (y) (g (g y))))
((f (lambda (x) (* x x))) 3)
```

Break: 5 minutes

Efficiency Practice

Fall 2019 Final Q6d

(1 pt) Circle the term that fills in the blank: the `is_palindrome` function defined below runs in `____` time in the length of its input.

Constant Logarithmic Linear Quadratic Exponential None of these

```
def is_palindrome(s):
    """Return whether a list of numbers s is a palindrome."""
    return all([s[i] == s[len(s) - i - 1] for i in range(len(s))])
```

Assume that `len` runs in constant time and `all` runs in linear time in the length of its input. Selecting an element of a list by its index requires constant time. Constructing a `range` requires constant time.

Summer 2022 Final Q4c

https://cs61a.org/exam/su22/final/61a-su22-final.pdf#page=15

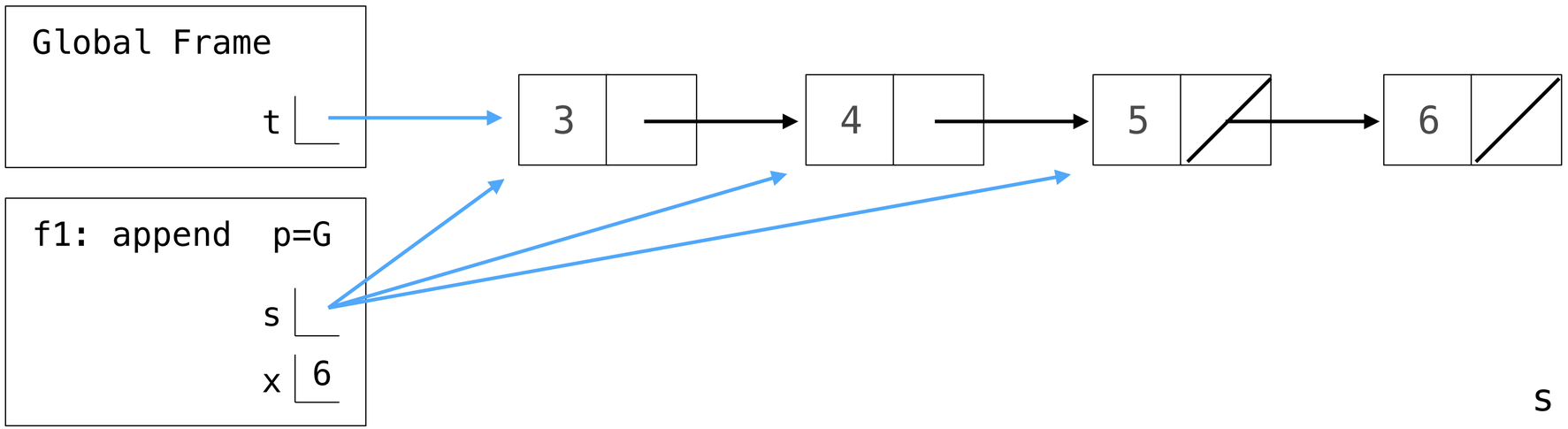
More Linked Lists Practice

Linked List Mutation

To change the contents of a linked list, assign to first and rest attributes

Example: Append x to the end of non-empty s

```
>>> t = Link(3, Link(4, Link(5)))
>>> append(t, 6)
>>> t
Link(3, Link(4, Link(5, Link(6))))
```




```
s = s.rest

s.rest = Link(x)
```

Recursion and Iteration

Many linked list processing functions can be written both iteratively and recursively

Recursive approach:

- What recursive call do you make?
- What does this recursive call do/return?
- How is this result useful in solving the problem?

```
def append(s, x):
    """Append x to the end of non-empty s.
    >>> append(s, 6)  # returns None!
    >>> print(s)
    <3 4 5 6>
    """
    if ___s.rest is not Link.empty___:
        append(__s.rest__, __x__)
    else:
        ___s.rest = Link(x)___
```

Iterative approach:

- Describe a process that solves the problem.
- Figure out what additional names you need to carry out this process.
- Implement the process using those names.

```
def append(s, x):
    """Append x to the end of non-empty s.
    >>> append(s, 6)  # returns None!
    >>> print(s)
    <3 4 5 6>
    """
    while ___s.rest is not Link.empty___:
        ___s = s.rest___
    ___s.rest = Link(x)___
```

Example: Pop

Implement pop, which takes a linked list s and positive integer i. It removes and returns the element at index i of s (assuming s.first has index 0).

```
def pop(s, i):
    """Remove and return element i from linked list s for positive i.
    >>> t = Link(3, Link(4, Link(5, Link(6))))
    >>> pop(t, 2)
    5
    >>> pop(t, 2)
    6
    >>> pop(t, 1)
    4
    >>> t
    Link(3)
    """
    assert i > 0 and i < length(s)
    for x in range(  i - 1  ):
        s = s.rest
    result = s.rest.first
    s.rest = s.rest.rest
    return   result
```