Scheme Lists

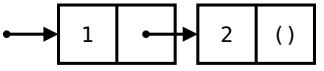
Class outline:

- Lists
- Quotation
- List procedures
- Exercises

Scheme lists

Constructing a list

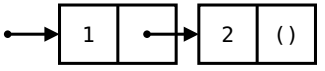
Scheme lists are linked lists.



Python (with our `Link` class:)

Constructing a list

Scheme lists are linked lists.

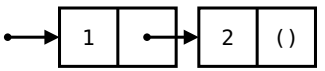


Python (with our `Link` class:)

```
Link(1, Link(2))
```

Constructing a list

Scheme lists are linked lists.



Python (with our `Link` class:)

```
Link(1, Link(2))
```

Scheme (with the `cons` form:)

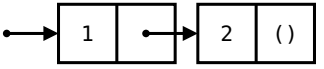
```
(cons 1 (cons 2 nil))
```

`nil` is the empty list.

Lists are written in parentheses with space-separated elements:

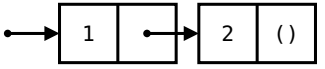
```
(cons 1 (cons 2 (cons 3 (cons 4 nil))))    ; (1 2 3 4)
```

Accessing list elements



Python access:

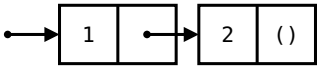
Accessing list elements



Python access:

```
lst = Link(1, Link(2))
lst.first  # 1
lst.rest   # Link(2)
```

Accessing list elements



Python access:

```
lst = Link(1, Link(2))
lst.first  # 1
lst.rest   # Link(2)
```

Scheme access:

```
(define lst (cons 1 (cons 2 nil)))
(car lst)  ; 1
(cdr lst)  ; (2)
```

- `car`: Procedure that returns the first element of a list
- `cdr`: Procedure that returns the rest of the list

Remember: "cdr" = "Cee Da Rest"

The list procedure

The built-in `list` procedure takes in an arbitrary number of arguments and constructs a list with the values of these arguments:

```
(list 1 2 3)                          ; (1 2 3)
(list 1 (list 2 3) 4)
(list (cons 1 (cons 2 nil)) 3 4)
```

Procedure reference: list

The list procedure

The built-in `list` procedure takes in an arbitrary number of arguments and constructs a list with the values of these arguments:

```
(list 1 2 3)                          ; (1 2 3)
(list 1 (list 2 3) 4)                 ; (1 (2 3) 4)
(list (cons 1 (cons 2 nil)) 3 4)
```

Procedure reference: list

The list procedure

The built-in `list` procedure takes in an arbitrary number of arguments and constructs a list with the values of these arguments:

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(list 1 2 3)                          ; (1 2 3)
(list 1 (list 2 3) 4)                 ; (1 (2 3) 4)
(list (cons 1 (cons 2 nil)) 3 4)      ; ((1 2) 3 4)
```

Procedure reference: list

Quotation

Quoting symbols

Symbols typically refer to values:

```
(define a 1)
(define b 2)
(list a b)
```

Quotation is used to refer to symbols directly:

```
(list 'a 'b)
(list 'a b)
```

The `'` is shorthand for the `quote` form:

```
(list (quote a) (quote b))
```

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(list a b)     ; (1 2)
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(define a 1)
(define b 2)
(list a b)     ; (1 2)
```

Quotation is used to refer to symbols directly:

```
(list 'a 'b)   ; (a b)
(list 'a b)    ; (a 2)
```

The `'` is shorthand for the `quote` form:

```
(list (quote a) (quote b))   ; (a b)
```

Quoting lists

Combinations can be quoted to form lists.

```
'(a b c)          ; (a b c)
(car '(a b c))
(cdr '(a b c))
```

Remember: quoted symbols are not evaluated.

Quoting lists

Combinations can be quoted to form lists.

```
'(a b c)         ; (a b c)
(car '(a b c)) ; a
(cdr '(a b c))
```

Remember: quoted symbols are not evaluated.

Quoting lists

Combinations can be quoted to form lists.

```
'(a b c)         ; (a b c)
(car '(a b c)) ; a
(cdr '(a b c)) ; (b c)
```

Remember: quoted symbols are not evaluated.

List procedures

length

`length` returns the length of a list.

```
(length '(1 2))
(length '())
(length nil)
(length 123)
```

Scheme built-in procedures: List manipulation

length

`length` returns the length of a list.

```
(length '(1 2))    ; 2
(length '())
(length nil)
(length 123)
```

Scheme built-in procedures: List manipulation

length

`length` returns the length of a list.

```
(length '(1 2))    ; 2
(length '())       ; 0
(length nil)
(length 123)
```

Scheme built-in procedures: List manipulation

length

`length` returns the length of a list.

```
(length '(1 2))    ; 2
(length '())       ; 0
(length nil)       ; 0
(length 123)
```

Scheme built-in procedures: List manipulation

length

`length` returns the length of a list.

```
(length '(1 2))    ; 2
(length '())       ; 0
(length nil)       ; 0
(length 123)       ; Error!
```

Scheme built-in procedures: List manipulation

null?

`null?` returns whether a list is empty or not.

```
(null? '())
(null? nil)
(null? '(1 2))
(null? 123)
```

Scheme built-in procedures: Type checking

null?

`null?` returns whether a list is empty or not.

```
(null? '())       ; #t
(null? nil)
(null? '(1 2))
(null? 123)
```

Scheme built-in procedures: Type checking

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`null?` returns whether a list is empty or not.

```
(null? '())       ; #t
(null? nil)       ; #t
(null? '(1 2))
(null? 123)
```

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null?

`null?` returns whether a list is empty or not.

```
(null? '())       ; #t
(null? nil)       ; #t
(null? '(1 2))    ; #f
(null? 123)
```

Scheme built-in procedures: Type checking

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`null?` returns whether a list is empty or not.

```
(null? '())       ; #t
(null? nil)       ; #t
(null? '(1 2))    ; #f
(null? 123)       ; #f
```

Scheme built-in procedures: Type checking

append

`append` returns the result of appending the items of all provided lists into a single list in the order provided.

```
(append '(1 2) '(3 4))
(append '(1 2) '(3 4) '(5 6))
```

Scheme built-in procedures: List manipulation

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`append` returns the result of appending the items of all provided lists into a single list in the order provided.

```
(append '(1 2) '(3 4))          ; (1 2 3 4)
(append '(1 2) '(3 4) '(5 6))
```

Scheme built-in procedures: List manipulation

append

`append` returns the result of appending the items of all provided lists into a single list in the order provided.

```
(append '(1 2) '(3 4))          ; (1 2 3 4)
(append '(1 2) '(3 4) '(5 6))   ; (1 2 3 4 5 6)
```

Scheme built-in procedures: List manipulation

map

`(map <proc> <lst>)` returns a new list created by applying `proc` to each item in `lst`

```
(map abs '(-1 -2 3 4))
(map - '(1 2))
```

Scheme built-in procedures: List manipulation

map

`(map <proc> <lst>)` returns a new list created by applying `proc` to each item in `lst`

```
(map abs '(-1 -2 3 4))    ; (1 2 3 4)
(map - '(1 2))
```

Scheme built-in procedures: List manipulation

map

`(map <proc> <lst>)` returns a new list created by applying `proc` to each item in `lst`

```
(map abs '(-1 -2 3 4))    ; (1 2 3 4)
(map - '(1 2))            ; (-1 -2)
```

Scheme built-in procedures: List manipulation

filter

`(filter <pred> <lst>)` returns a new list consisting only of elements of `lst` for which `pred` is true.

```
(filter even? '(0 1 2 3 4 5))
(filter odd? '(0 1 2 3 4 5))
```

Scheme built-in procedures: List manipulation

filter

`(filter <pred> <lst>)` returns a new list consisting only of elements of `lst` for which `pred` is true.

```
(filter even? '(0 1 2 3 4 5))    ; (0 2 4)
(filter odd? '(0 1 2 3 4 5))
```

Scheme built-in procedures: List manipulation

filter

`(filter <pred> <lst>)` returns a new list consisting only of elements of `lst` for which `pred` is true.

```
(filter even? '(0 1 2 3 4 5))    ; (0 2 4)
(filter odd? '(0 1 2 3 4 5))     ; (1 3 5)
```

Scheme built-in procedures: List manipulation

reduce

`(reduce <combiner> <lst>)` returns the result of sequentially combining each element in `lst` using `combiner` (a two-arg procedure).

```
(reduce + '(1 2 3 4 5))
(reduce expt '(1 2 3 4 5))
(reduce expt '(2 3 4 5))
```

Scheme built-in procedures: List manipulation

reduce

`(reduce <combiner> <lst>)` returns the result of sequentially combining each element in `lst` using `combiner` (a two-arg procedure).

```
(reduce + '(1 2 3 4 5))          ; (15)
(reduce expt '(1 2 3 4 5))
(reduce expt '(2 3 4 5))
```

Scheme built-in procedures: List manipulation

reduce

`(reduce <combiner> <lst>)` returns the result of sequentially combining each element in `lst` using `combiner` (a two-arg procedure).

```
(reduce + '(1 2 3 4 5))          ; (15)
(reduce expt '(1 2 3 4 5))       ; (1)
(reduce expt '(2 3 4 5))
```

Scheme built-in procedures: List manipulation

reduce

`(reduce <combiner> <lst>)` returns the result of sequentially combining each element in `lst` using `combiner` (a two-arg procedure).

```
(reduce + '(1 2 3 4 5))          ; (15)
(reduce expt '(1 2 3 4 5))       ; (1)
(reduce expt '(2 3 4 5))         ; (11529215046068469 76)
```

Scheme built-in procedures: List manipulation

List equality

```
(define list1 '(a b c))
(define list2 '(a b c))
```

For lists, `(eq? a b)` returns whether `a` and `b` are the same list in memory.

```
(eq? list1 list2)
```

Scheme built-in procedures: Boolean operations

List equality

```
(define list1 '(a b c))
(define list2 '(a b c))
```

For lists, `(eq? a b)` returns whether `a` and `b` are the same list in memory.

```
(eq? list1 list2)  #f
```

Scheme built-in procedures: Boolean operations

List equality

```
(define list1 '(a b c))
(define list2 '(a b c))
```

For lists, `(eq? a b)` returns whether `a` and `b` are the same list in memory.

```
(eq? list1 list2)  #f
```

While `(equal? a b)` returns whether `a` and and `b` are equivalent. Two lists are considered equivalent if `(car a)` is equivalent to `(car b)` and `(cdr a)` is equivalent to `(cdr b)`.

```
(equal? list1 list2)
```

Scheme built-in procedures: Boolean operations

List equality

```
(define list1 '(a b c))
(define list2 '(a b c))
```

For lists, `(eq? a b)` returns whether `a` and `b` are the same list in memory.

```
(eq? list1 list2)  #f
```

While `(equal? a b)` returns whether `a` and and `b` are equivalent. Two lists are considered equivalent if `(car a)` is equivalent to `(car b)` and `(cdr a)` is equivalent to `(cdr b)`.

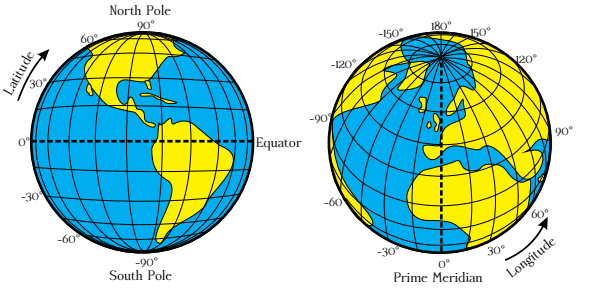
```
(equal? list1 list2)  #t
```

Scheme built-in procedures: Boolean operations

Exercises

North of equator?

Implement `(north_of_eq point)`, a procedure that takes `point`, a two-element list with a latitude and longitude, and returns whether `point` is north of the Equator.

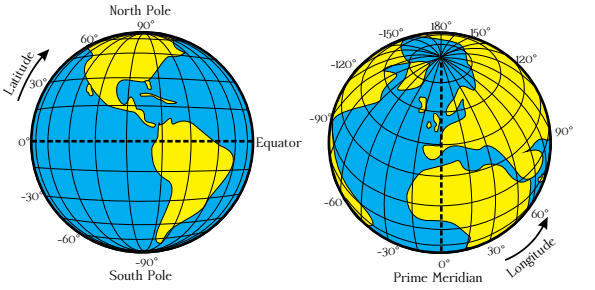



```
(define (north_of_eq point)

)
(expect (north_of_eq '(67 10)) #t)
(expect (north_of_eq '(67 -10)) #t)
(expect (north_of_eq '(-67 10)) #f)
(expect (north_of_eq '(-67 -10)) #f)
```

North of equator? (Solution)

Implement `(north_of_eq point)`, a procedure that takes `point`, a two-element list with a latitude and longitude, and returns whether `point` is north of the Equator.




```
(define (north_of_eq point)
    (> (car point) 0)
)
(expect (north_of_eq '(67 10)) #t)
(expect (north_of_eq '(67 -10)) #t)
(expect (north_of_eq '(-67 10)) #f)
(expect (north_of_eq '(-67 -10)) #f)
```

All north?

Implement `(all_north_of_eq points)`, a procedure that takes `points`, a list of two-element lists, and returns whether all the `points` are north of the equator.

```
(define (all_north_of_eq points)


)

(expect (all_north_of_eq '( (67 10) (14 43) (37 -122))) #t)
(expect (all_north_of_eq '( (-67 10) (14 43) (37 -122))) #f)
(expect (all_north_of_eq '( (67 10) (14 43) (-37 -122))) #f)
(expect (all_north_of_eq '()) #t)
```

All north? (Solution 1)

Implement `(all_north_of_eq points)`, a procedure that takes `points`, a list of two-element lists, and returns whether all the `points` are north of the equator.

```
(define (all_north_of_eq points)
    (= (length (filter north_of_eq points)) (length points))
)

(expect (all_north_of_eq '( (67 10) (14 43) (37 -122))) #t)
(expect (all_north_of_eq '( (-67 10) (14 43) (37 -122))) #f)
(expect (all_north_of_eq '( (67 10) (14 43) (-37 -122))) #f)
(expect (all_north_of_eq '()) #t)
```

All north? (Solution 2)

Implement `(all_north_of_eq points)`, a procedure that takes `points`, a list of two-element lists, and returns whether all the `points` are north of the equator.

```
(define (all_north_of_eq points)
    (cond
        ( (null? points) #t)
        ( (north_of_eq (car points)) (all_north_of_eq (cdr points)))
        (else #f)
    )
)

(expect (all_north_of_eq '( (67 10) (14 43) (37 -122))) #t)
(expect (all_north_of_eq '( (-67 10) (14 43) (37 -122))) #f)
(expect (all_north_of_eq '( (67 10) (14 43) (-37 -122))) #f)
(expect (all_north_of_eq '()) #t)
```

Countdown list

Implement `countdown_list`, a procedure which takes a number `n` and returns a list with all the numbers from `n` down to 1.

```
(define (countdown_list n)


)

(expect (countdown_list 3) (3 2 1))
(expect (countdown_list 1) (1))
```

Countdown list (Solution)

Implement `countdown_list`, a procedure which takes a number `n` and returns a list with all the numbers from `n` down to 1.

```
(define (countdown_list n)
    (if
        (= n 0) nil
        (cons n (countdown_list (- n 1)))
    )
)

(expect (countdown_list 3) (3 2 1))
(expect (countdown_list 1) (1))
```

Countup list

Implement `countup_list`, a procedure which takes a number `n` and returns a list with all the numbers from 1 up to (and including) `n`.

```
(define (countup_list n)


)

(expect (countup_list 3) (1 2 3))
(expect (countup_list 1) (1))
```

Countup list (Solution)

Implement `countup_list`, a procedure which takes a number `n` and returns a list with all the numbers from 1 up to (and including) `n`.

```
(define (countup_list n)
    (if
        (= n 0) nil
        (append (countup_list (- n 1)) (cons n nil) )
    )
)

(expect (countup_list 3) (1 2 3))
(expect (countup_list 1) (1))
```