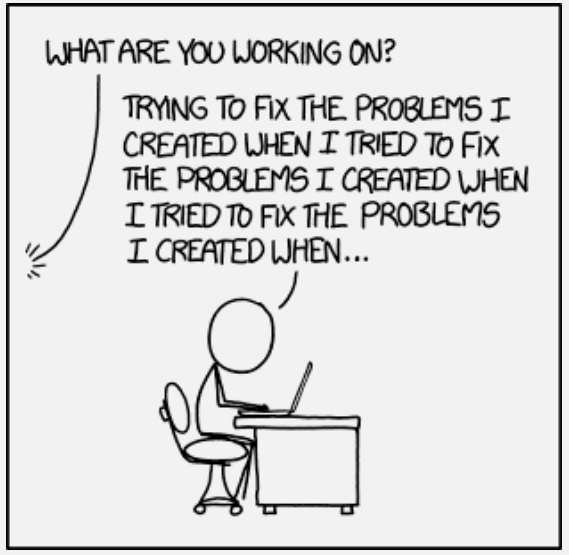
UMass Boston Computer Science

CS450 High Level Languages (section 2)

Recursive Data Definitions

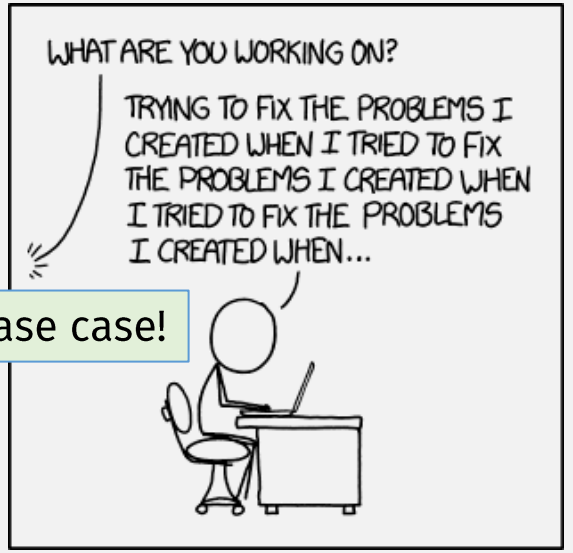
Monday, October 2, 2023



Logistics

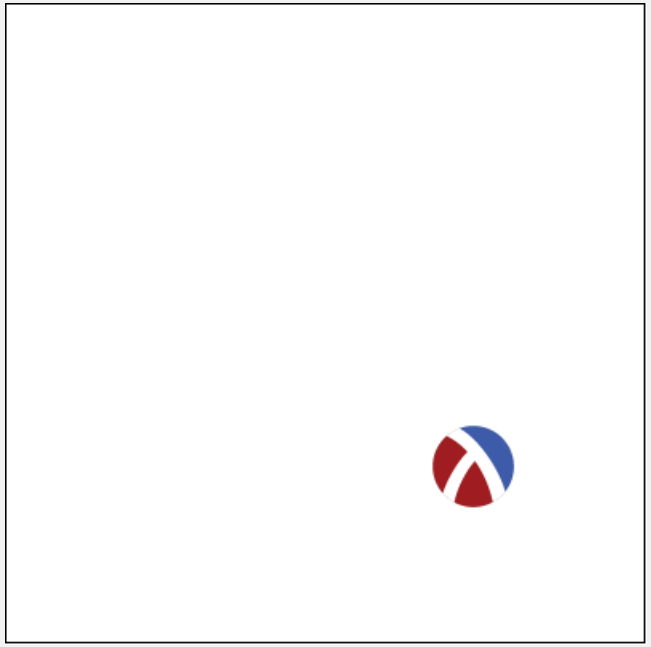
- HW 2 in
  - ~~due: Sun 10/1 11:59 pm EST~~
- HW 3 delayed
  - out: tomorrow
  - due: Sun 10/15 11:59 pm EST
  - (2 weeks)
- No class: next Monday 10/9
  - Indigenous Peoples Day

(What's wrong with this recursion?)



Last Time

Bouncing Ball



Last Time

Multi-ball Animation

Design a **`big-bang`** animation that:

- Start: **a single ball, moving with random x and y velocity**

- If a ball "hits" an edge:
  - for **vertical** edge, **flip x velocity direction**
  - for **horizontal** edge, **flip y velocity direction**

Randomness

[bracketed args] = optional

```
(random k [rand-gen]) → exact-nonnegative-integer?
  k : (integer-in 1 4294967087)
  rand-gen : pseudo-random-generator?
           = (current-pseudo-random-generator)
```

When called with an integer argument *k*, returns a random exact integer in the range `0` to *k*-1.

Optional arg Default value

```
(random min max [rand-gen]) → exact-integer?
  min : exact-integer?
  max : (integer-in (+ 1 min) (+ 4294967087 min))
  rand-gen : pseudo-random-generator?
           = (current-pseudo-random-generator)
```

When called with two integer arguments *min* and *max*, returns a random exact integer in the range *min* to *max*-1.

What is "**random**"???

A **pseudorandom number generator** (**PRNG**), also known as a **deterministic random bit generator** (**DRBG**),[1] is an algorithm for generating a sequence of numbers whose properties approximate the properties of sequences of random numbers. The PRNG-generated sequence is not truly random, because it is completely determined by an initial value, called the PRNG's *seed*

Not secure!
e.g., for generating passwords

vs

A **cryptographically secure pseudorandom number generator** (**CSPRNG**) or **cryptographic pseudorandom number generator** (**CPRNG**) is a pseudorandom number generator (PRNG) with properties that make it suitable for use in cryptography.

Random Functions: Same Recipe (almost)!

```
;; A Velocity is a non-negative integer
;; Interp: reresents pixels/tick change in a ball coordinate
(define MAX-VELOCITY 10)
```

```
;; random-velocity : -> Velocity
;; returns a random velocity between 0 and MAX-VELOCITY
(define (random-velocity)
  (random MAX-VELOCITY))
```

Functions can have zero args

Random functions have no examples

```
(check-true (< (random-velocity) MAX-VELOCITY))
(check-true (>= (random-velocity) 0))
(check-true (integer? (random-velocity)))
(check-pred (λ (v) (and (integer? v)
                        (< v MAX-VELOCITY)
                        (>= v 0)))
            (random-velocity))
```

Can still **test!**
Just less precise

```
;; random-x    : -> ???
;; random-y    : -> ???
;; random-ball : -> ???
```

Last Time

Multi-ball Animation

Design a **`big-bang`** animation that:

- Start: **a single ball, moving with random x and y velocity**
- On a click: **add a ball at random location with random velocity**
- If a ball "hits" an edge:
  - for **vertical** edge, **flip x velocity direction**
  - for **horizontal** edge, **flip y velocity direction**

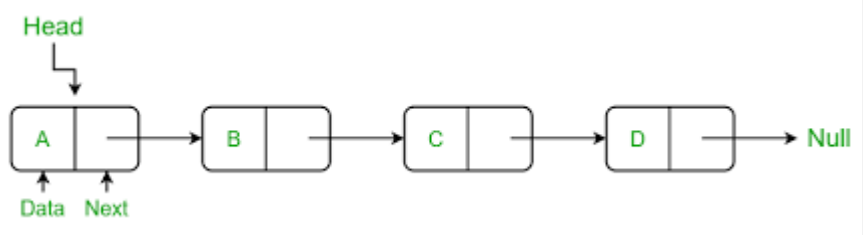
```
;; A WorldState is … an unknown number of balls!
```

Last Time

Arbitrary Size Data - Lists

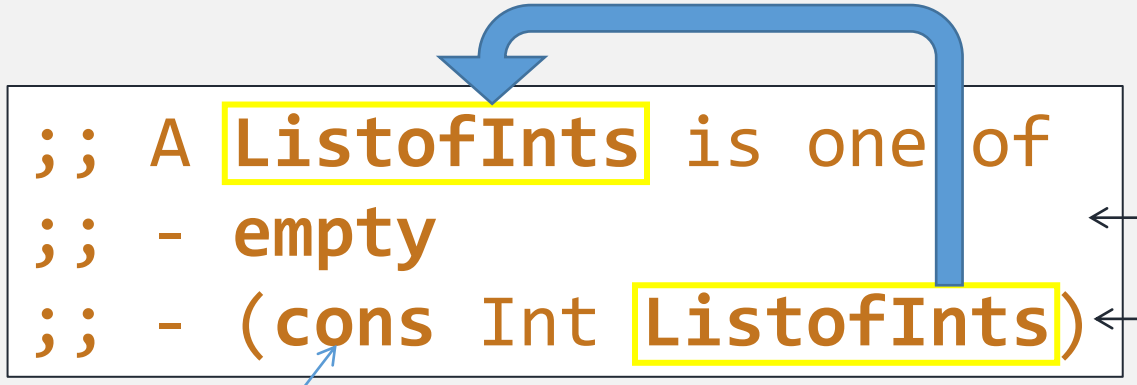
In C

```
struct node
{ int data;
  struct node *next; } *head;
```



This is a **self-referential** (i.e., **recursive**!) definition!

Racket List Data Definition Example



Empty (**base**) case

Non-empty (**recursive**) case

cons = “node”

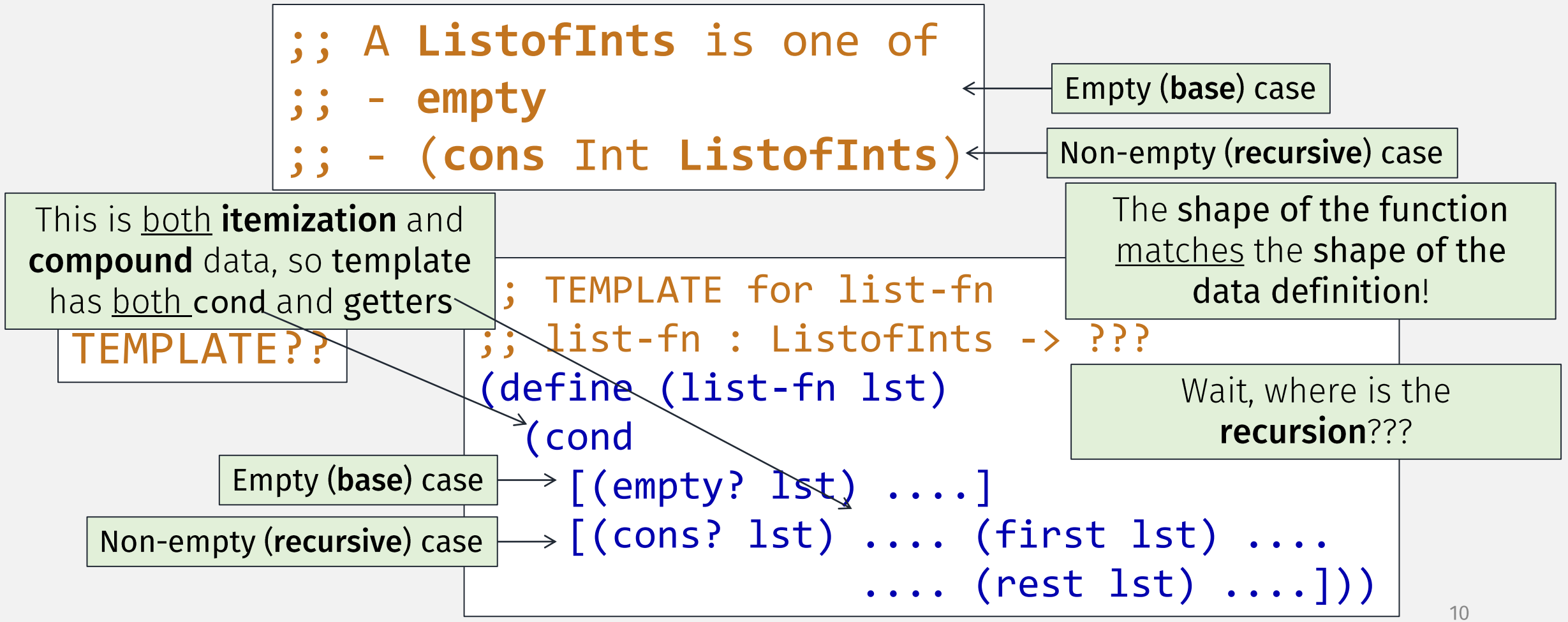
Recursive!
(using a definition to define itself)

TEMPLATE??

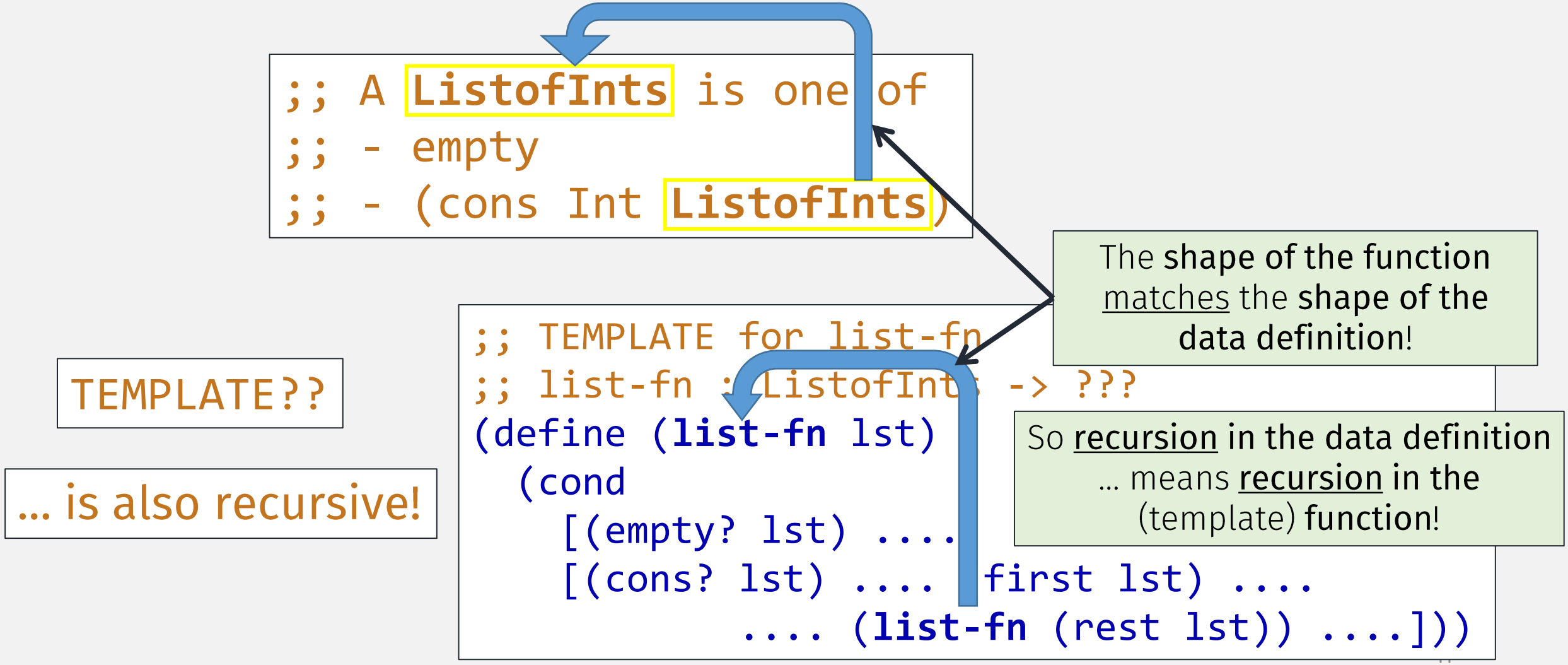
(how can we **use a list of ints** to define a list of ints?!?)

Recursion is only valid if there is <u>both</u>
- A **base** case
- A **recursive** case

Racket List Data Definition Example

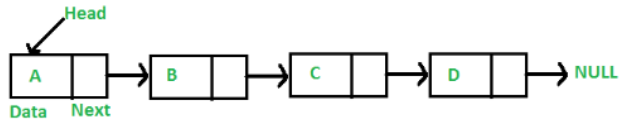


Racket List Data Definition Example



Racket Recursive List Fn Example: sum

Given a singly linked list. The task is to find the sum of nodes of the given linked list.



Task is to do A + B + C + D.

Examples:

geeksforgeeks.com

```
Input: 7->6->8->4->1
Output: 26
Sum of nodes:
7 + 6 + 8 + 4 + 1 = 26

Input: 1->7->3->9->11->5
Output: 36
```

Description!

Examples!

```
;; TEMPLATE for list-fn
;; list-fn : ListofInts -> ???
(define (list-fn lst)
  (cond
    [(empty? lst) ....]
    [(cons? lst) .... (first lst) ....
                 .... (list-fn (rest lst)) ....]))
```

Racket Recursive List Fn Example: sum

Design Recipe:
Now fill in template!
(with arithmetic)

```
;; Returns sum of list of ints
;; sum-lst: ListofInts -> Int
(define (sum-lst lst)
  (cond
    [(empty? lst) ....]
    [else .... (first lst) ....
          .... (sum-lst (rest lst)) ....]))
```

Racket Recursive List Fn Example: sum

```
;; Returns sum of list of ints
;; sum-lst: ListofInts -> Int
(define (sum-lst lst)
  (cond
    [(empty? lst) 0]
    [else .... (first lst) ....
          .... (sum-lst (rest lst)) ....]))
```

Racket Recursive List Fn Example: sum

```
;; Returns sum of list of ints
;; sum-lst: ListofInts -> Int
(define (sum-lst lst)
  (cond
    [(empty? lst) 0]
    [else (+ (first lst)
             (sum-lst (rest lst)))]))
```

Racket Recursive List Fn Example: rev

```
;; TEMPLATE for list-fn
;; list-fn : ListofInts -> ???
(define (list-fn lst)
  (cond
    [(empty? lst) ....]
    [else .... (first lst) ....
          .... (list-fn (rest lst)) ....]))
```

Racket Recursive List Fn Example: rev

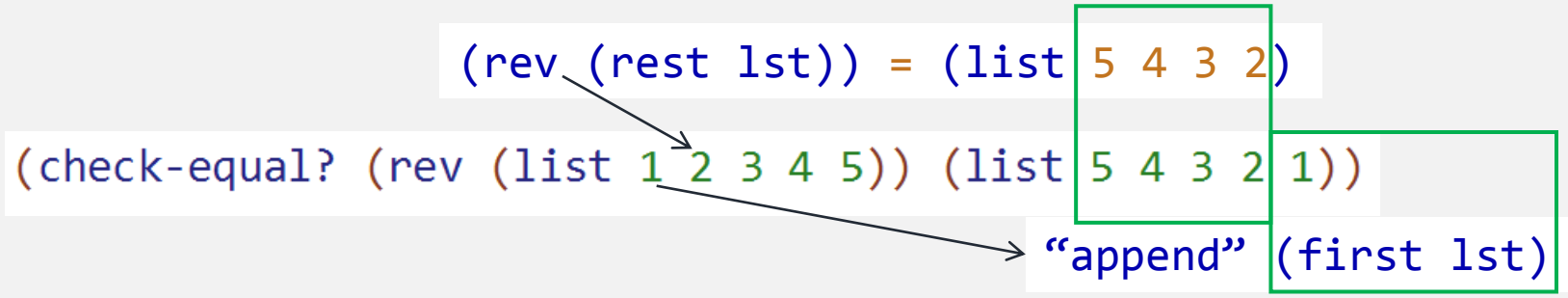
Design Recipe:
Now fill in template!
(with arithmetic)

```
;; reverses a list of ints
;; rev: ListofInts -> ListofInts
(define (rev lst)
  (cond
    [(empty? lst) ....]
    [else .... (first lst) ....
          .... (rev (rest lst)) ....]))
```

Racket Recursive List Fn Example: rev

```
;; reverses a list of ints
;; rev: ListofInts -> ListofInts
(define (rev lst)
  (cond
    [(empty? lst) empty]
    [else .... (first lst) ....
          .... (rev (rest lst)) ....]))
```

Racket Recursive List Fn Example: rev




```
;; reverses a list of ints
;; rev: ListofInts -> ListofInts
(define (rev lst)
  (cond
    [(empty? lst) empty]
    [else (append (rev (rest lst))
                  (list (first lst)))]))
```

Recursive rev fn, with “temp” vars (preview)

```
;; TEMPLATE for list-fn
;; list-fn : ListofInts -> ???
(define (list-fn lst)
  (cond
    [(empty? lst) ....]
    [else .... (first lst) ....
          .... (list-fn (rest lst)) ....]))
```

Recursive rev fn, with “temp” vars (later)

```
;; reverses a list of ints
;; rev : ListofInts -> ListofInts
(define (rev lst)
  (cond
    [(empty? lst) ....]
    [else .... (first lst) ....
          .... (rev (rest lst)) ....]))
```

Recursive rev fn, with “temp” vars (later)

An internal “**helper**” function adds a “temp” variable
(main fn calls helper fn)

Still follows design recipe!

```
;; reverses a list of ints
;; rev : ListofInts -> ListofInts
(define (rev lst rev-lst-so-far)
  (define (rev/tmp lst rev-lst-so-far)
    (cond
      [(empty? lst) ....]
      [else .... (first lst) ....
            .... (rev/tmp (rest lst) ....)
            .... rev-lst-so-far ....]))
  (rev/tmp lst empty))
```

Tmp var = reversed list “so far” (initially `empty`)

Recursive rev fn, with “temp” vars (later)

```
;; reverses a list of ints
;; rev : ListofInts -> ListofInts
(define (rev lst rev-lst-so-far)
  (define (rev/tmp lst rev-lst-so-far)
    (cond
      [(empty? lst) rev-lst-so-far]
      [else .... (first lst) ....
            .... (rev/tmp (rest lst)
            .... rev-lst-so-far ....
  (rev/tmp lst empty))
```

Now figure out how to “combine” these pieces (with “arithmetic”)

Recursive rev fn, with “temp” vars (later)

```
;; reverses a list of ints
;; rev : ListofInts -> ListofInts
(define (rev lst rev-lst-so-far)
  (define (rev/tmp lst rev-lst-so-far)
    (cond
      [(empty? lst) rev-lst-so-far]
      [else (rev/tmp
                (rest lst)
                (cons (first lst) rev-lst-so-far))]))
  (rev/tmp lst empty))
```

Add next list item to reversed list “so far”

Multi-ball Animation

Design a **`big-bang`** animation that:

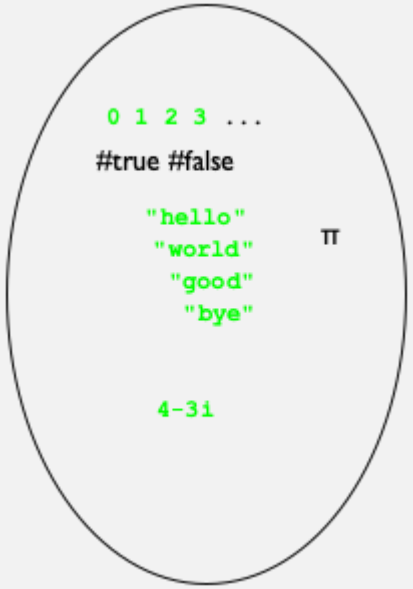
- Start: **a single ball, moving with random x and y velocity**
- On a click: **add a ball at random location, with random velocity**
- If any ball "hits" an edge:
  - if it's a **vertical** edge, **the x velocity should flip direction**
  - If it's a **horizontal** edge, **the y velocity should flip direction**

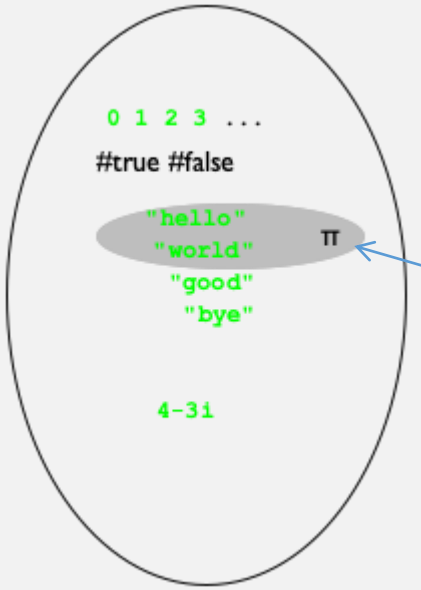
```
;; A WorldState is … an unknown number of balls!
```

```
;; A WorldState is … a list of balls!
```

Interlude: Data Definitions (ch 5.7)

All possible data values





A **data definition**
= (a named) subset of all possible values

We are defining which data values are valid for our program!

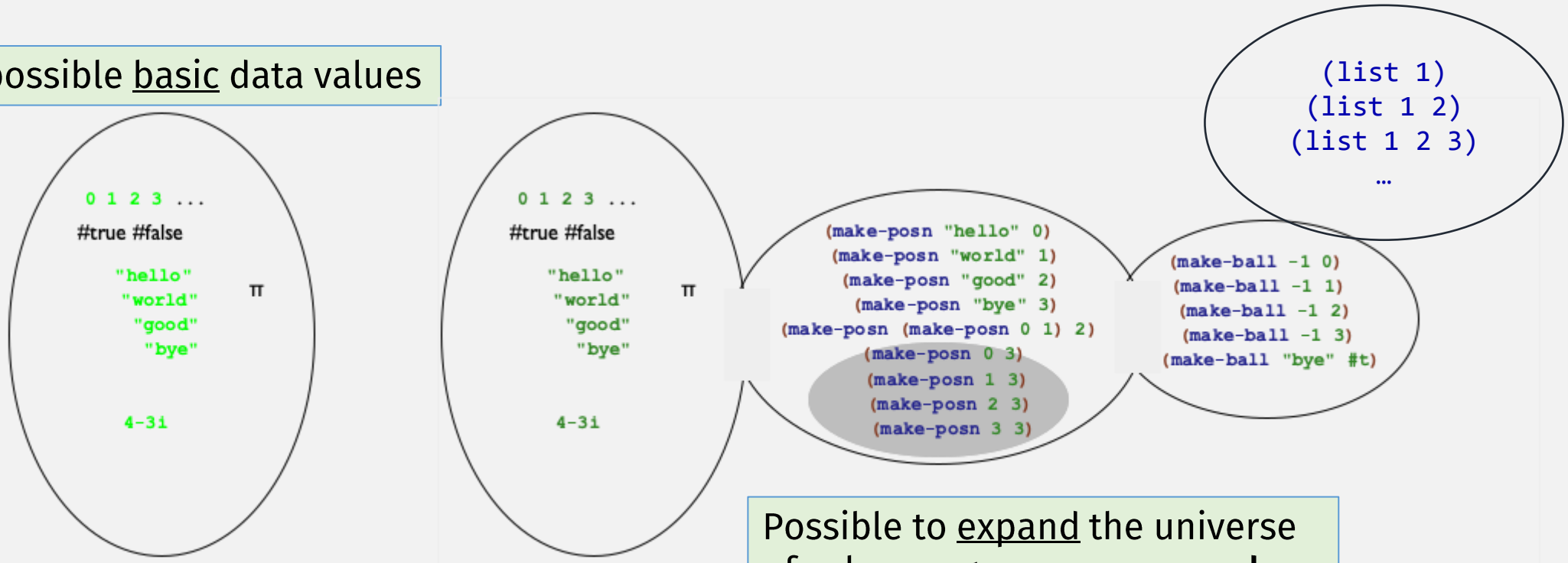
All programs are data manipulators …

So this must be the first step of programming!

Also makes “error handling” easy

Interlude: Data Definitions (ch 5.7)

All possible basic data values



Possible to expand the universe of values, e.g., new **compound data definitions** (`struct`, or other data structure)

Multi-ball Animation

Design a **`big-bang`** animation that:

- Start: **a single ball, moving with random x and y velocity**
- On a click: **add a ball at random location, with random velocity**
- If any ball "hits" an edge:
  - if it's a **vertical** edge, **the x velocity should flip direction**
  - If it's a **horizontal** edge, **the y velocity should flip direction**

```
;; A WorldState is … an unknown number of balls!
```

```
;; A WorldState is … a list of balls!
```

Ball

ball

```
;; A WorldState is a
(struct world [x y xvel yvel] #:transparent)
;; wher
;; x: XCoord - represents x coordinate of ball center in animation
;; y: YCoord - represents y coordinate of ball center in animation
;; xvel: Integer - represents x velocity, where
;;                 postive = to the right, negative = to the left
;; yvel: Integer - represents y vel, where
;;                 positive = down, negative = up
```

```
;; A ListofBall is one of
;; - null
;; - (cons Ball ListofBall)
```

```
;; A WorldState is a ListofBall
```

```
(define (main)
  (big-bang (list (random-ball))
    [on-mouse mouse-handler]
    [on-tick next-world]
    [to-draw render-world]))
```

```
;; A WorldState is a ListofBall
```

These need to be updated to handle new `WorldState` data def

next-world

List **template!**

```
;; next-world : WorldState -> WorldState
;; Computes the next world state on a tick
(define (next-world w)
  (cond
    [(empty? w) ....]
    [else .... (first w) ....
          .... (next-world (rest w)) ....]))
```

Ball

Create one function per “task”

```
(check-equal? (next-world (list (make-ball 0 0 1 1)))
              (list (next-ball (make-ball 0 0 1 1))))
```

next-ball

This was the previous “next-world” function!

```
(define (next-ball b)
  (match-define (ball x y xvel yvel) b)
  (define new-xvel
    (if (ball-in-scene/x? x) xvel (- xvel)))
  (define new-yvel
    (if (ball-in-scene/y? y) yvel (- yvel)))
  (define new-x (+ x new-xvel))
  (define new-y (+ y new-yvel))
  (ball new-x new-y new-xvel new-yvel))
```

next-world

List **template!**

```
;; next-world : WorldState -> WorldState
;; Computes the next world state on a tick
(define (next-world w)
  (cond
    [(empty? w) ....]
    [else .... (first w) ....
          .... (next-world (rest w)) ....]))
```

Ball

Create one function per “task”

```
(check-equal? (next-world (list (make-ball 0 0 1 1)))
              (list (next-ball (make-ball 0 0 1 1))))
```

next-world

```
;; next-world : WorldState -> WorldState
;; Computes the next world state on a tick
(define (next-world w)
  (cond
    [(empty? w) empty]
    [else .... (first w) ....
          .... (next-world (rest w)) ....]))
```

next-world

```
;; next-world : WorldState -> WorldState
;; Computes the next world state on a tick
(define (next-world w)
  (cond
    [(empty? w) empty]
    [else (cons (next-ball (first w))
                (next-world (rest w)))]))
```

render-world

List **template!**

```
;; render-world : WorldState -> Image
;; Draws the given worldstate as an image
(define (render-world w)
  (cond
    [(null? w) EMPTY-SCENE]
    [else (place-ball (first w) (render-world (rest w)))]))
```

Separate “draw” function for the ball

For multi-arg function, you choose which (argument's) template to use

Enumeration

```
;; mouseHandler : WorldState XCoord YCoord MouseEvent -> WorldState
;; Inserts a new ball on mouse click
(define (mouse-handler w x y mevt)
  (cond
    [(click? mevt) (cons (make-ball/random-velocity x y) w)]
    [else w ]))
```

Enumeration template
(collapsed)

Multi-ball Animation: more?

Design a **`big-bang`** animation that:

- Start: a single ball, moving with random x and y velocity
- On a click: add a ball at random location, with random velocity
  - And random size?
  - And random color?
- If any ball "hits" an edge:
  - if it's a vertical edge, the x velocity should flip direction
  - If it's a horizontal edge, the y velocity should flip direction

```
;; A WorldState is … a list of balls!
```

Check-In Quiz 10/2

on gradescope

(due 1 minute before midnight)