CS3:
Introduction to Symbolic Programming

Lecture 6:
Finishing up basic recursion

Spring 2006

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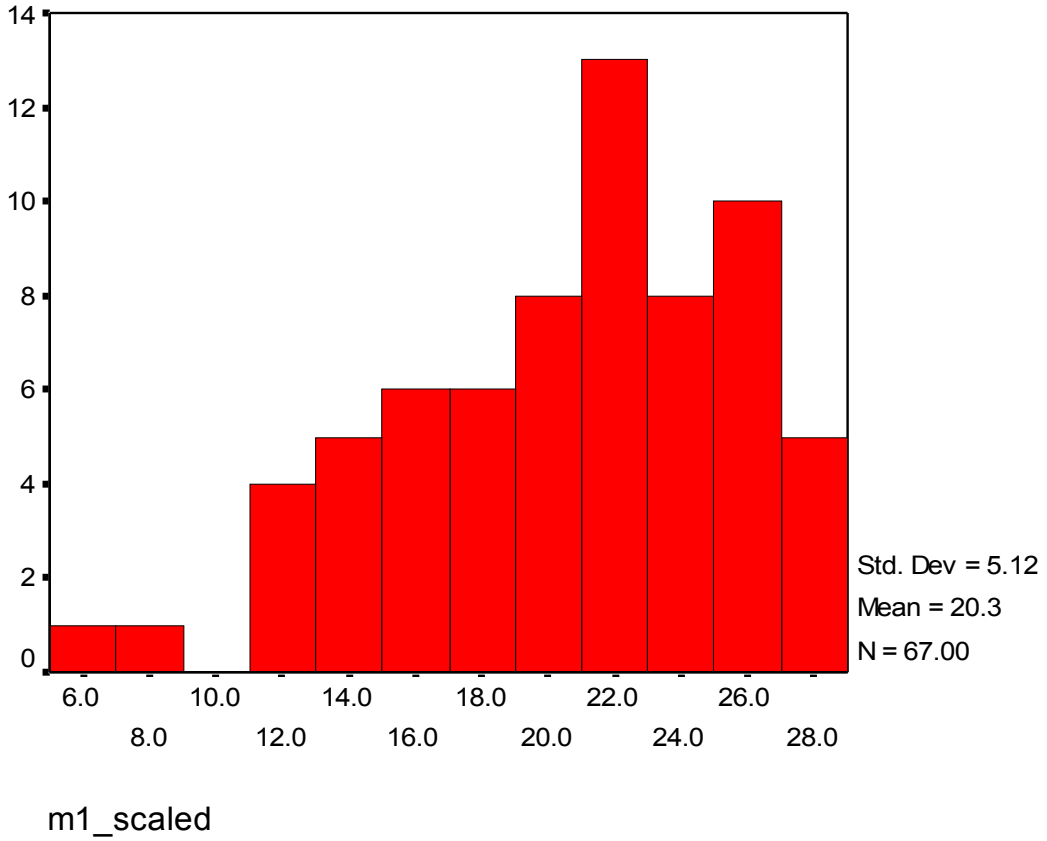
Schedule

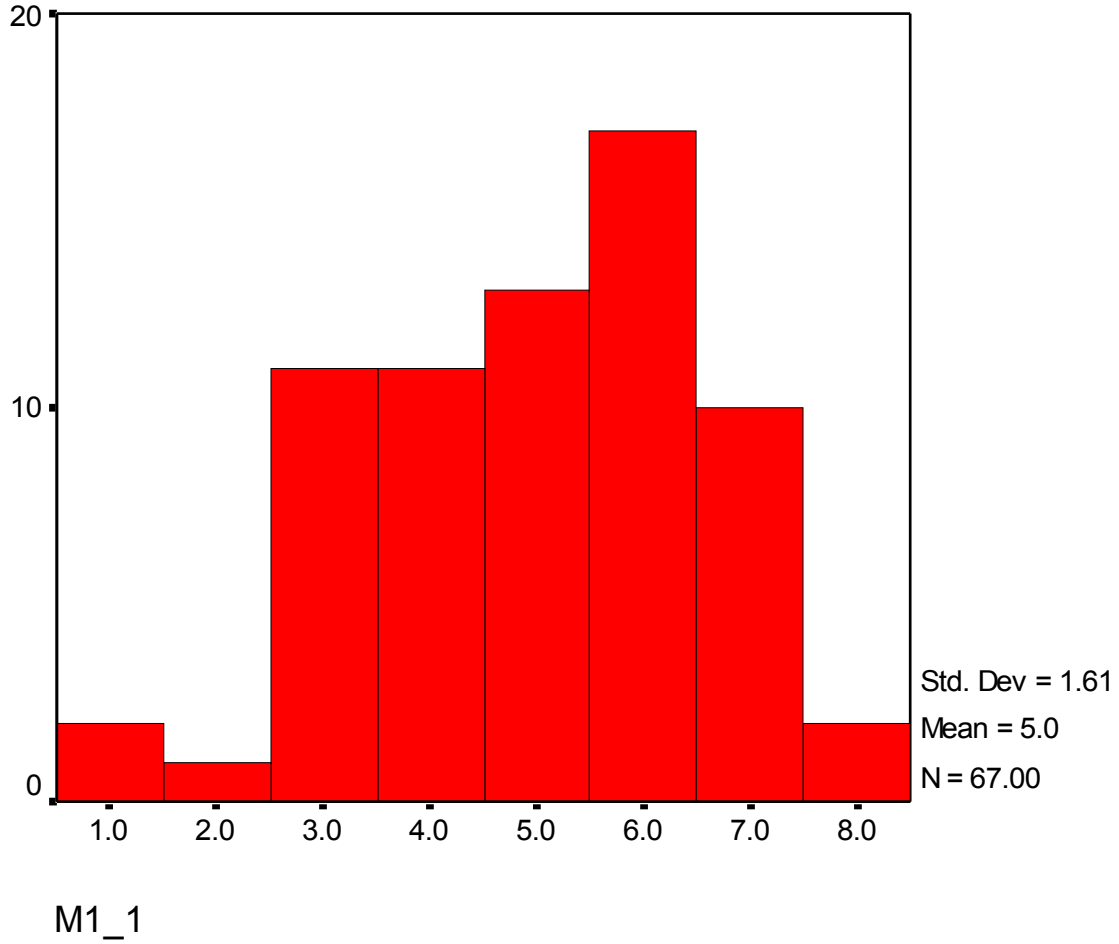
7	Feb 27-Mar 3	Lecture: *Midterm 1* Lab: Recursion III
8	Mar 6-10	Lecture: Finishing recursion Lab: Miniproject #2: Number names
9	Mar 13-17	Introduction to Higher Order Procedures
10	Mar 20-24	More HOF
11	Mar 27-31	*(Spring Break)*

Midterm 1

- You did quite well (IMO)
- If you need a re-grade, talk to your TA first, and then see the TA that graded that question
- Solutions will be available soon on the portal (check announcements).

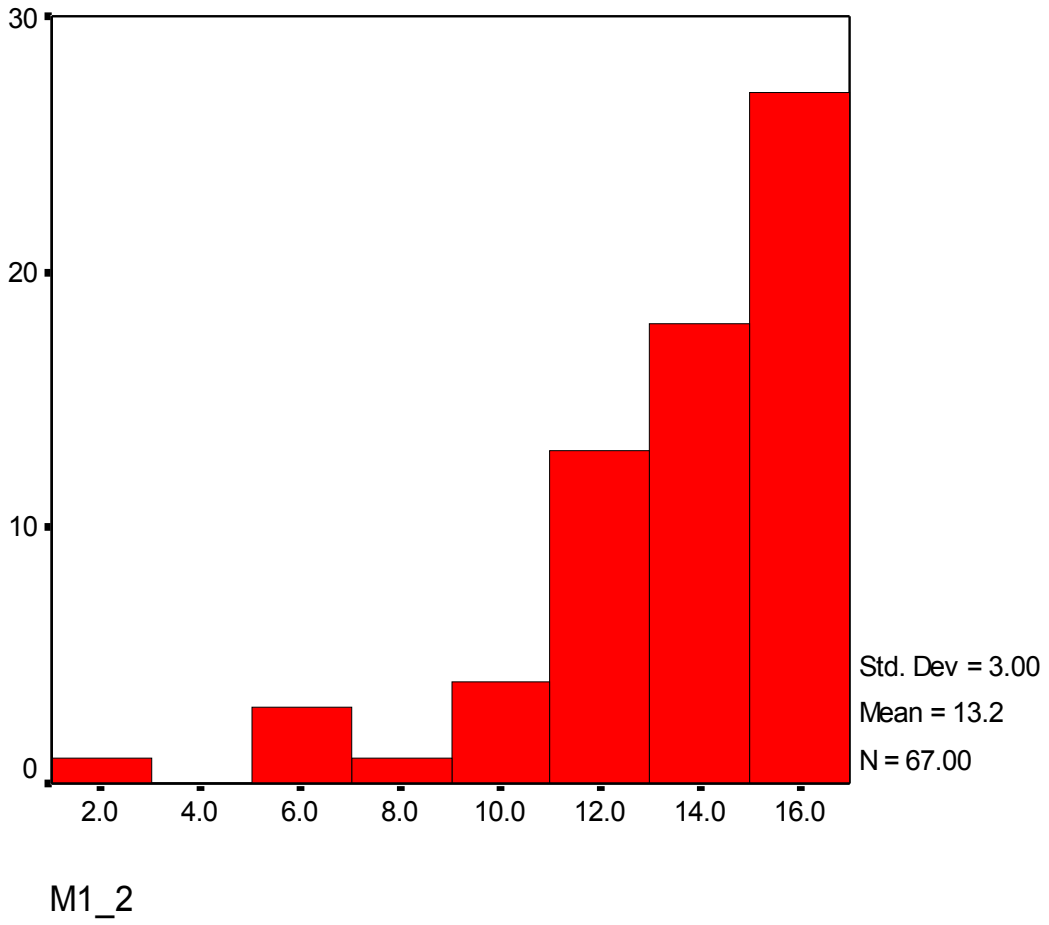


Question 1: fill in the blanks



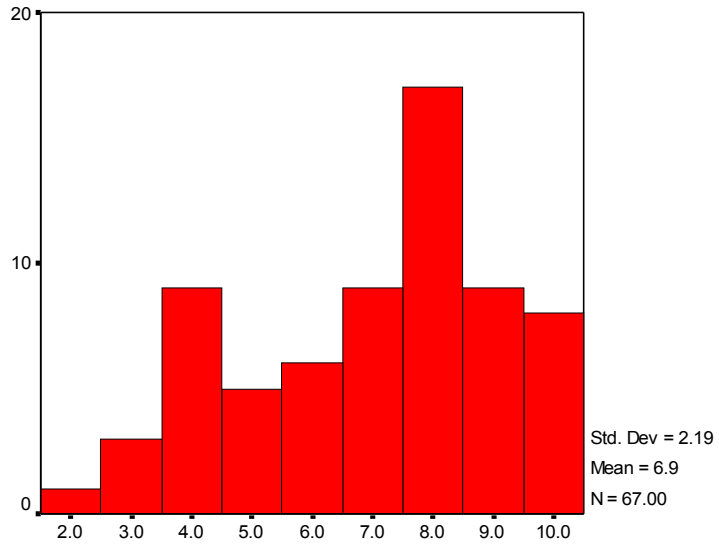
Q2: Roman numerals, and recursion

- You did quite well on the recursion question
  - (The TAs and I were worried about this one)
- Take home point (which you've got): A recursive solution will have a series of conditional cases, some recursive, some non-recursive

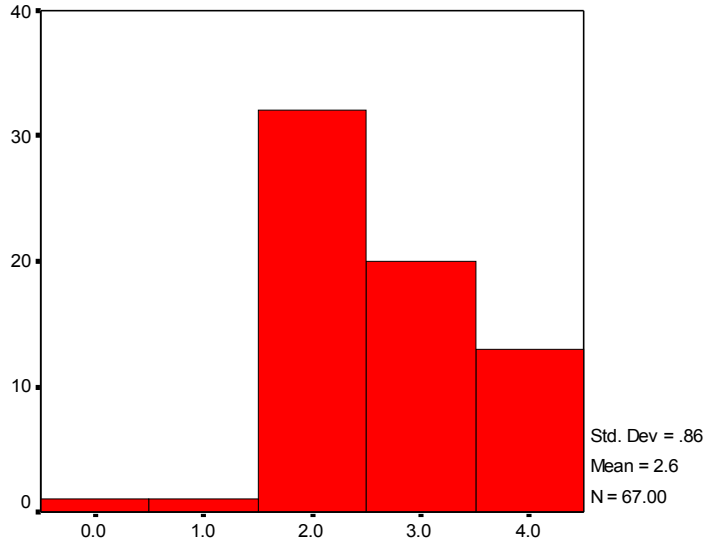


Q3: `between?`, and test cases

- **Writing test cases is an "art", especially when there are no clear cut 'cond' clauses**
  - **Test ALL possible outputs**
  - **Test all conditions that lead to a particular decision**



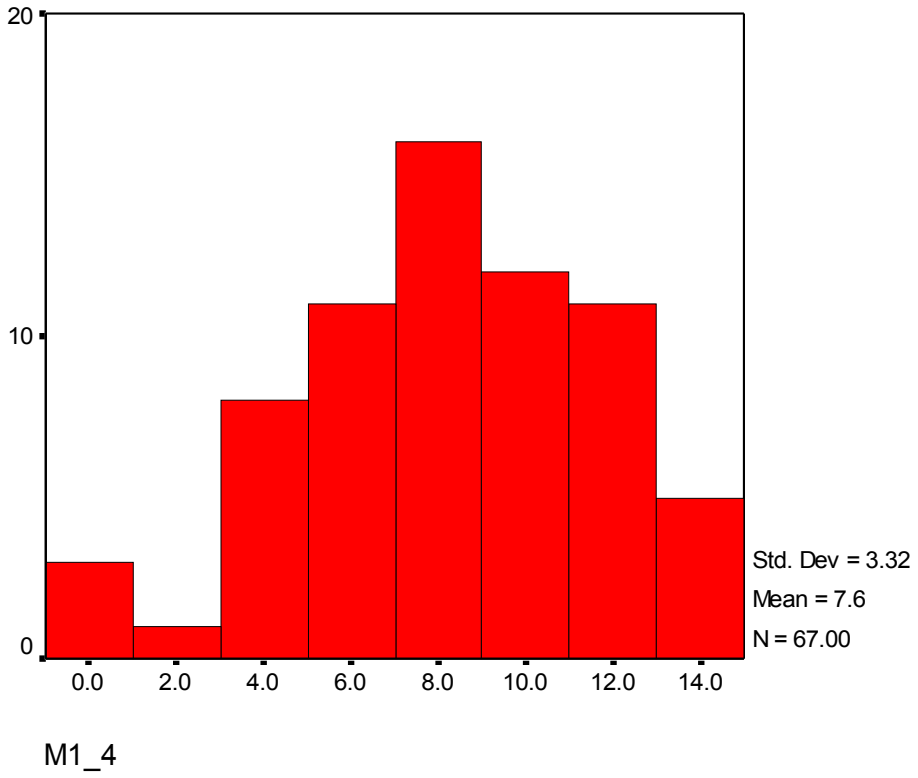
M1_3



M1_3C

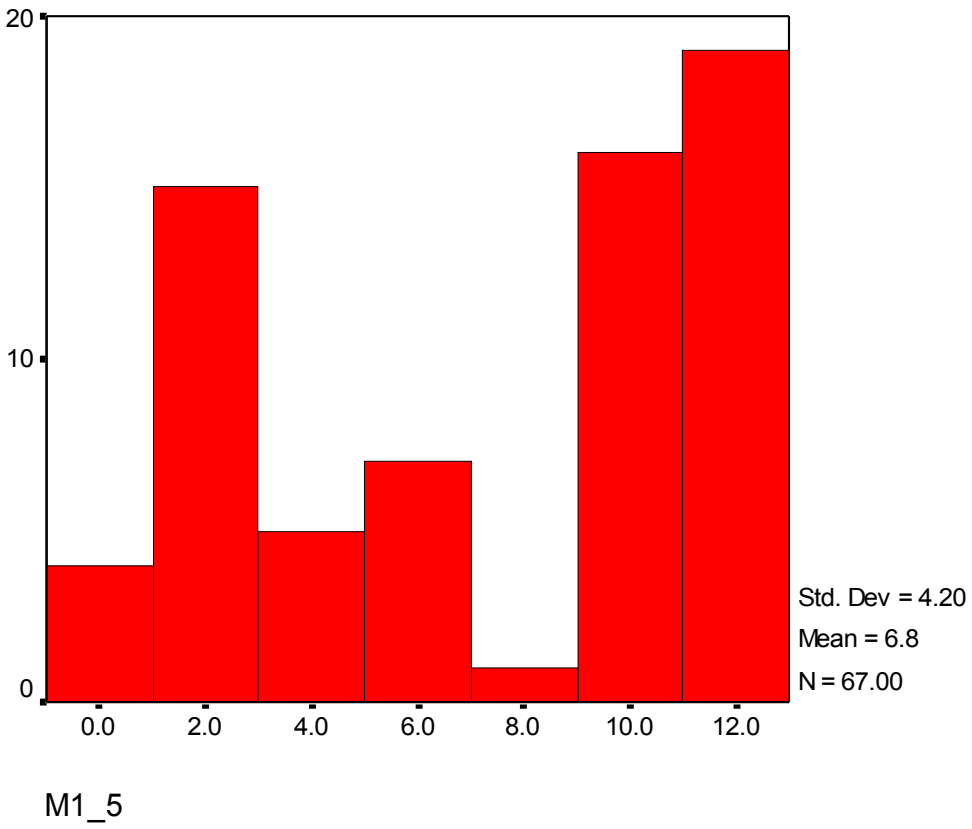
Q4: validating a scheme expression

- **This wasn't a great question in how it was "asked"**



Q5: sub-sentence using recursion

- **Many of you ran out of time**
- **Some nice solutions here (that I hadn't thought of)**



A solution for sub-sentence

```
(define (sub-sentence start len sent)
  (cond ((empty? sent)
         '())
        ((> start 1)
         (sub-sentence (- start 1) len (bf sent))
        ((> len 0)
         (se (first sent)
             (sub-sentence start (- len 1)(bf sent))))
        (else
         '())
        ))
```

Number Spelling Miniproject

- **Read *Simply Scheme*, page 233, which has hints**

- **Another hint (principle): don't force "everything" into the recursion.**
  - **Special/border cases may be easier to handle before you send yourself into a recursion**

"Tail" recursions

- **Accumulating recursions are sometimes called "tail" recursions (by TAs, me, etc).**
  - **But, not all recursions that keep track of a number are "tail" recursions.**

- **A tail recursion has no combiner, so it can end as soon as a base case is reached**
  - **Compilers can do this efficiently**
- **An embedded recursion needs to combine up all the recursive steps to form the answer**
  - **The poor compiler has to remember everything**

Tail or embedded? (1/3)

```
(define (length sent)
   (if (empty? sent)
      0
      (+ 1 (length (bf sent)))))
```

Embedded!

```
(length '(a b c d)) →
  (+ 1 (length '(b c d)))
  (+ 1 (+ 1 (length '(c d))))
  (+ 1 (+ 1 (+ 1 (length '(d)))))
  (+ 1 (+ 1 (+ 1 (+ 1 (length '())))))
  (+ 1 (+ 1 (+ 1 (+ 1 0))))
  (+ 1 (+ 1 (+ 1 1)))
  (+ 1 (+ 1 2))
  (+ 1 3)
  4
```

Tail or embedded? (2/3)

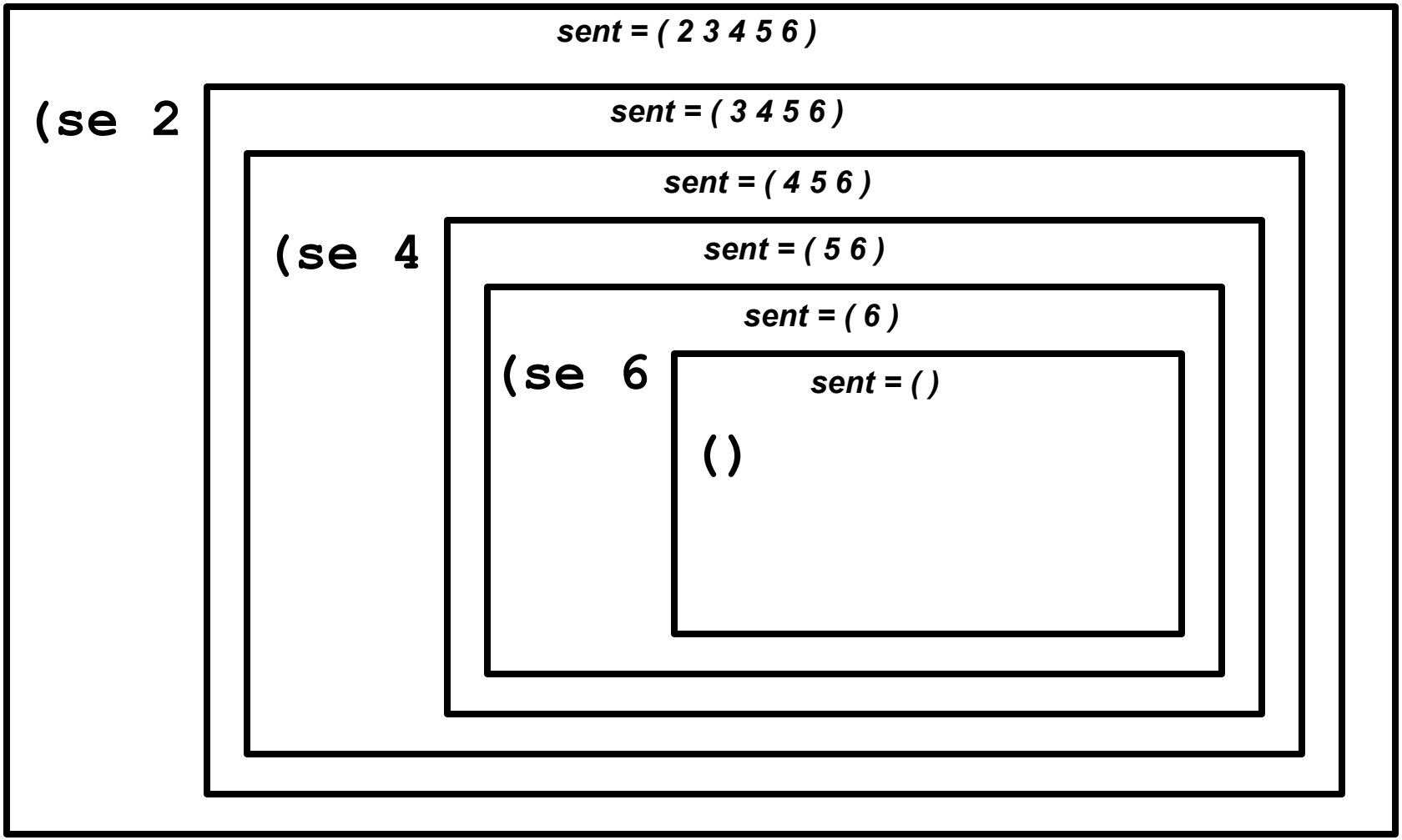
```
(define (sent-max sent)
  (if (empty? sent)
    '()
    (sent-max-helper (bf sent) (first sent))))

(define (sent-max-helper sent max-so-far)
  (if (empty? sent)
    max-so-far
    (sent-max-helper (bf sent)
                     (if (> max-so-far (first sent))
                         max-so-far
                         (first sent)))))
```

Tail or embedded? (3/3)

```
(define (find-evens sent)
  (cond ((empty? sent)          ;base case
         '()                )
        ((odd? (first sent)) ;rec case 1
         (find-evens (bf sent)) )
        (else                       ;rec case 2: even
         (se (first sent)
             (find-evens (bf sent))) )
        ))
```

```
> (find-evens '(2 3 4 5 6))
```



➔ (se 2 (se 4 (se 6 ())

➔ (2 4 6)

sub-sentence

```
(define (sub-sentence start len sent)
  (cond ((empty? sent)
         '())
        ((> start 1)
         (sub-sentence (- start 1) len (bf sent)))
        ((> len 0)
         (se (first sent)
             (sub-sentence start (- len 1)(bf sent))))
        (else
         '())
        ))
```

Advanced recursions (1/3)

"when it does more than one thing at a time"

- **Ones that traverse multiple sentences**
  - **E.g., `mad-libs` takes a sentence of replacement words [e.g., `'(fat Henry three)`] and a sentence to mutate [e.g.,**

    `'(I saw a * horse named * with * legs)`]

Advanced recursions (2/3)

- **Recursions that have an *inner* and an *outer* recursion**

```
(no-vowels '(I like to type)) → ("" lk t typ)

(l33t '(I like to type)) → (i 1i/<3 +0 +yP3)

(strip-most-popular-letter '(cs3 is the best class)) →
   (c3 i the bet cla)

(occurs-in? 'abc 'abxcde) → #f
```

Advanced recursions (3/3)

- **Tree recursion: multiple recursive calls in a single recursive step**
- **There are many, many others**

Tree recursion: fibonacci

- **The fibonacci sequence:**

  1 1 2 3 5 8 13 21 34 55

```
(define (fib n)
   (if (<= n 2)
      1                          ;; base case
      (+ (fib (- n 1))           ;; recursive case
         (fib (- n 2)))))
```

pair-all

- **Write `pair-all`, which takes a sentence of `prefixes` and a sentence of `suffixes` and returns a sentence pairing all `prefixes` to all `suffixes`.**
  - `(pair-all '(a b c) '(1 2 3))` ➔
    `(a1 b1 c1 a2 b2 c2 a3 b3 c3)`
  - `(pair-all '(spr s k) '(ite at ing ong))` ➔
    `(sprite sprat spring sprong site sat sing song kite kat king kong)`

binary

- **Write `binary`, a procedure to generate the possible binary numbers given `n` bits.**

```
(binary 1)→(0 1)
(binary 2)→(00 01 10 11)
(binary 3)→(000 001 010 011 100 101 110 111)
```