WELLESLEY

# Programming Languages

CS 251

*Fall 2021*

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## Functional Programming

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- They treat functions like other values in the language
- They emphasize recursion over iteration
- They do not allow mutation

## Mutation

**x = 5**
**x = 7**

**foo(x) = 15**
**foo(x) = 21**

Mutation: overwriting the value of a variable or data structure.

State: a mechanism for keeping track of the **current** values associated with variables.

*How is state different than memory?*

# Lambda Calculus

$$\boxed{\lambda y.\lambda x.y+x}$$

*Expresses a function that takes two arguments, x and y, and adds them.*

- Lambdas bind variables
- Lambda calculus describes computation using the concepts of function application, substitution, binding, and scope.
- There's no mutation in lambda calculus.

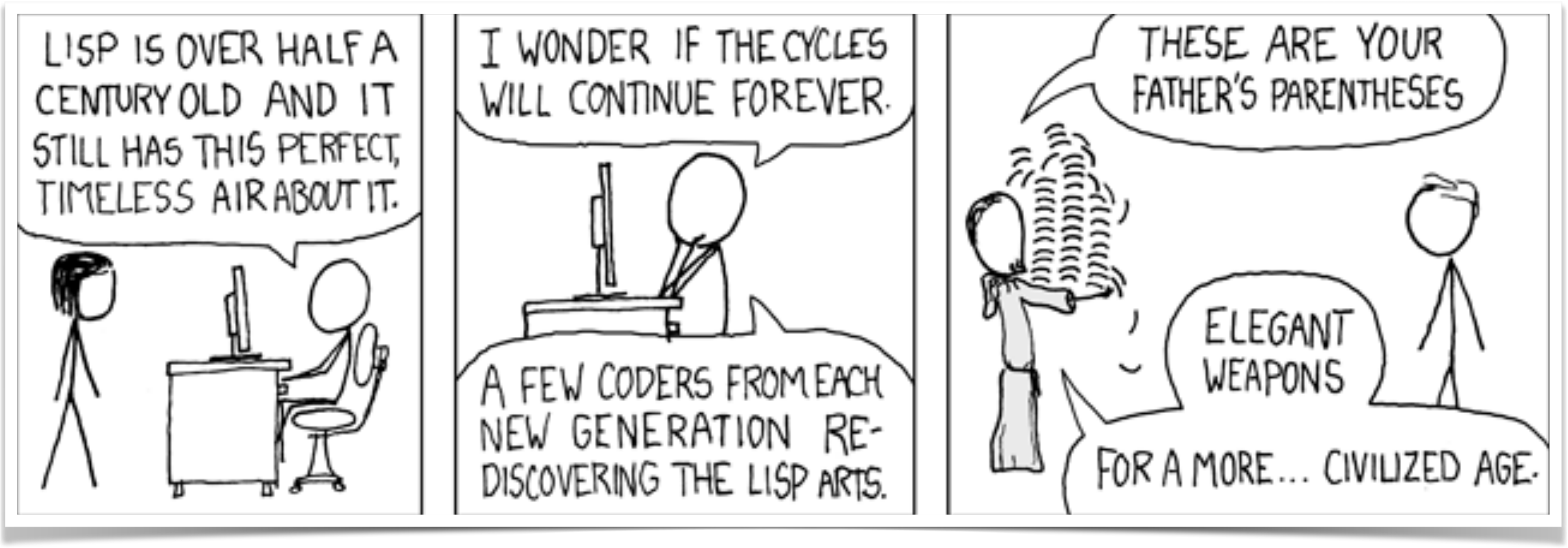
Turing showed that the classes of functions defined by $\lambda$-calculus and Turing machines coincide.

## Racket is Turing-complete (even without mutation)

*We just have to learn to think functionally*

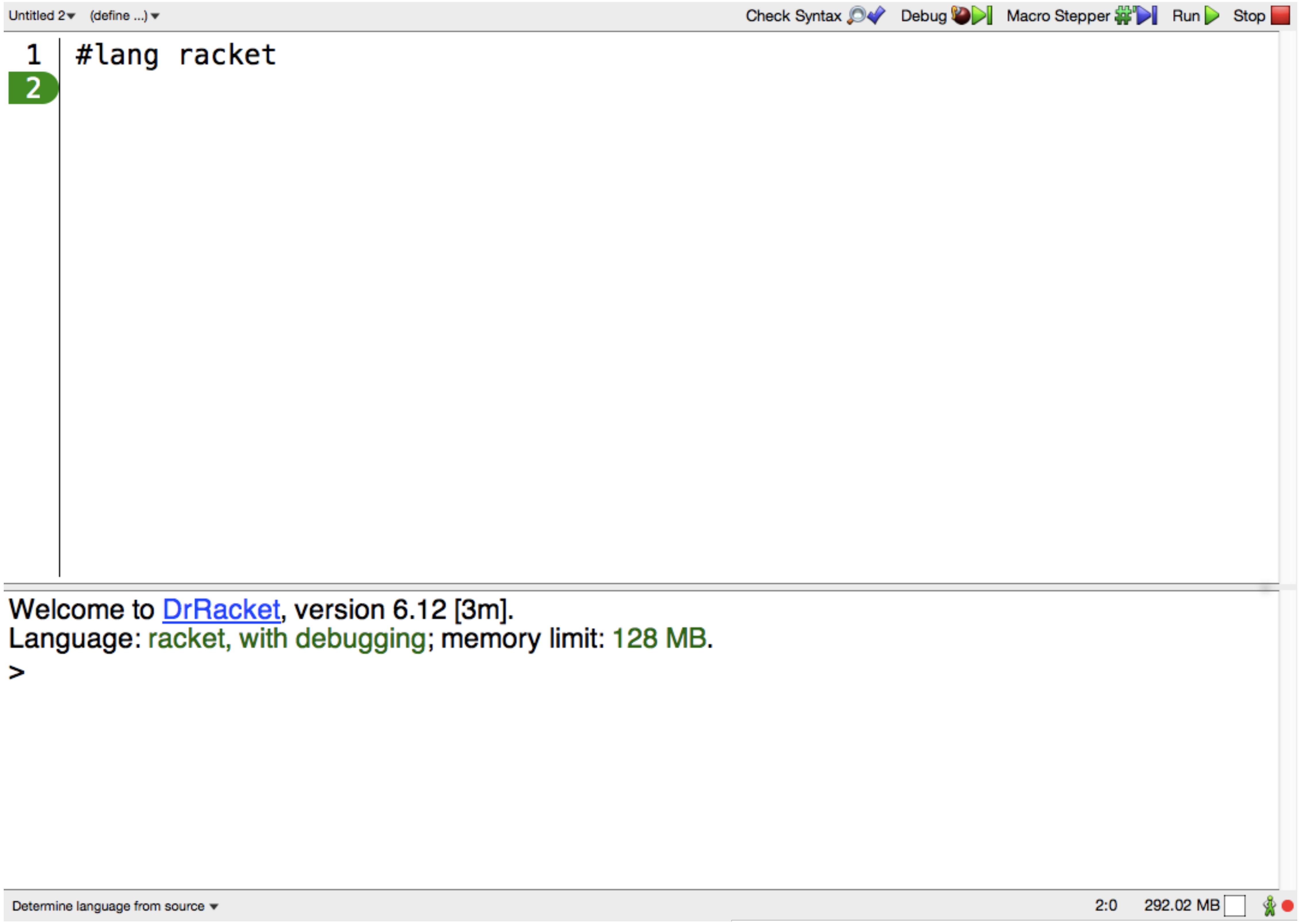
# Welcome to Racket

*You are now a Racketeer….*


LISP IS OVER HALF A CENTURY OLD AND IT STILL HAS THIS PERFECT, TIMELESS AIR ABOUT IT.
I WONDER IF THE CYCLES WILL CONTINUE FOREVER.
A FEW CODERS FROM EACH NEW GENERATION RE-DISCOVERING THE LISP ARTS.
THESE ARE YOUR FATHER'S PARENTHESES
ELEGANT WEAPONS
FOR A MORE... CIVILIZED AGE.

xkcd

# Dr. Racket



```
#lang racket

```

```
Welcome to DrRacket, version 6.12 [3m].
Language: racket, with debugging; memory limit: 128 MB.
>
```

# Basic Datatypes

| Booleans | Numbers |
|---|---|
| #t | 1 |
| #f | 1/2 |
| | 1.0 |

| Strings | Characters |
|---|---|
| “hi” | #\h |
| “h” | #\λ |

# Lists

```
(list “apple” “banana” “carrot”)

(list 1 2 3)

(list 1 “carrot”  3   #t   “cucumber”)
```

# Lists

In Racket, lists are recursively defined:
a list is either null, or a pair whose second item is a list.

Lists have two key methods: **first** and **rest**

```
> (first (list 1 2 3))
1

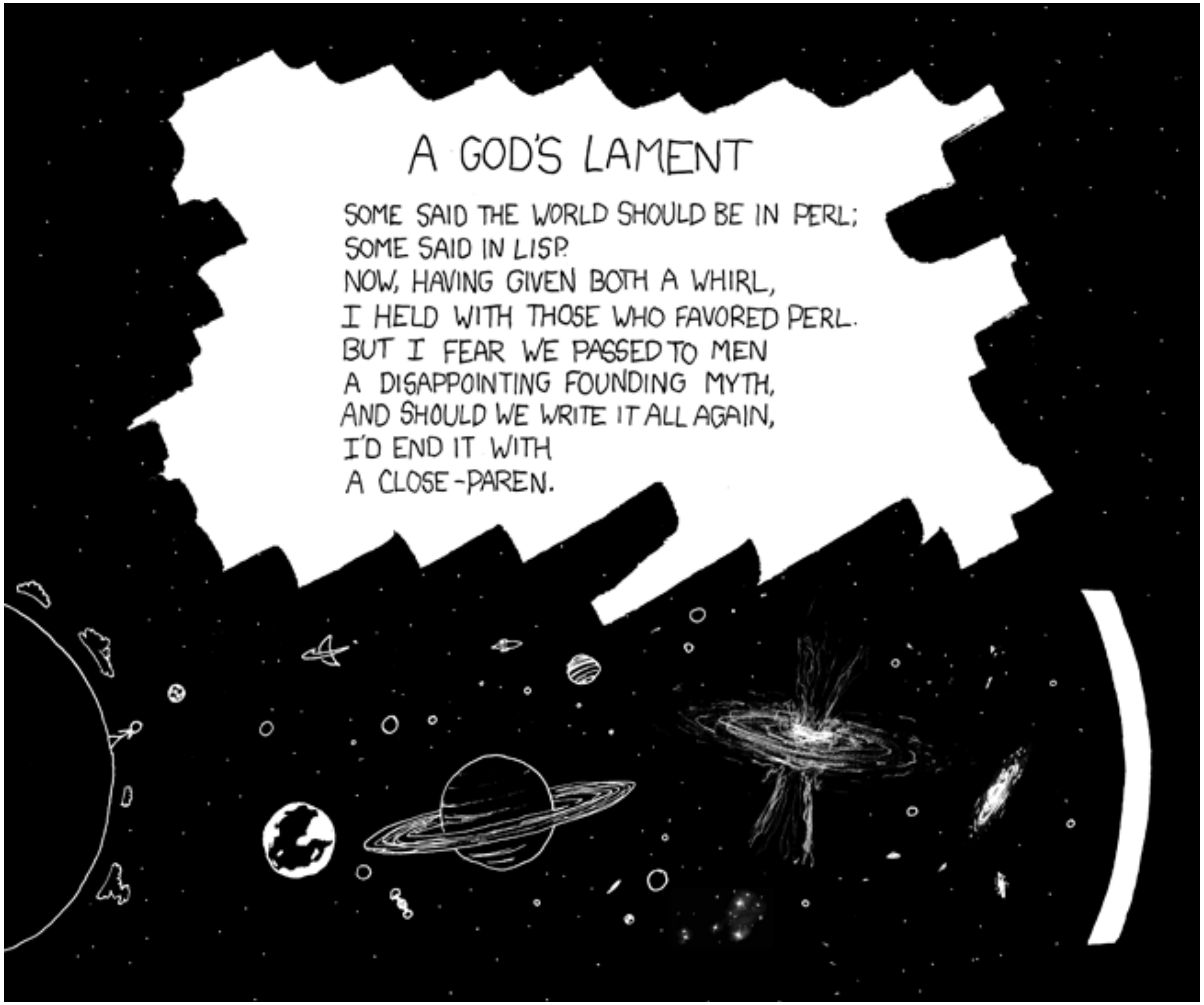
> (rest (list 1 2 3))
(list 1 2)
```

# Control Flow

```
(if (= x 5)        test
    #t             value if true
    #f)            value if false
```

```
(cond ((= x 0) (printf “x is 0”))
      ((= x 1) (printf “x is 1”))
      (else (printf “x is greater than 1”)))
```

# Why are there so many parentheses?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A CLOSE-PAREN.

xkcd

# Syntax

- Leaf: a value that can't be evaluated any further (also called an "atomic value" or a "literal")
- Leaves are unparenthesized in Racket
- Every non-leaf node in the syntax tree is marked by a pair of parentheses
- **Special forms** have a keyword after the open parenthesis: (**if** e1 e2 e3 )
- Most other parentheses mark function calls

# Variable definitions

- Syntax: (**define** id e)
- Example:

```
(define x 1)
> x
1
```

# Functions

- Syntax: (**define** (id) e)
- Examples:

```
(define (add)
          (+ 10 10))
```

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(define (hello-world)
          (printf “Hello world!”))
```

## Functions

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- Examples:

```
(define (add)
        (+ 10 10))

(define (hello-world)
        (display “Hello world!”))
```

🚧 **Warning: side effect** 🚧

# Side effects

- **Side effect**: any observable effect other than producing a value
- Functional programming languages tend to avoid side effects (mutation is a kind of side effect)
- Side effects make it **harder to reason formally** about a program’s behavior
- However, printing is very useful!

# Racket printing

- What’s the difference between **display**, **write**, and **print**?
- What does **displayln** do?

## Documentation

- Racket Guide:
  - https://docs.racket-lang.org/guide/index.html
- Racket Reference:
  - https://docs.racket-lang.org/reference/index.html

## Common Racket mistakes

# Common Racket mistakes

1. Wrap leaf values in parens: (17)
2. Use operators in infix rather than prefix position
3. Put arguments in parentheses with function name outside
4. Use unexpected keywords
5. Omit parentheses for non-leaf node