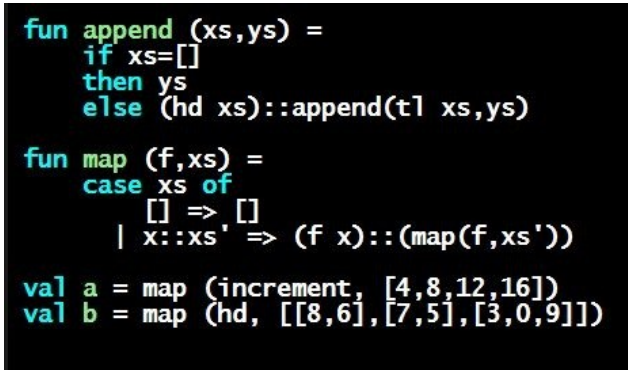

```
fun append (xs,ys) =
    if xs=[]
    then ys
    else (hd xs)::append(tl xs,ys)

fun map (f,xs) =
    case xs of
        [] => []
      | x::xs' => (f x)::(map(f,xs'))

val a = map (increment, [4,8,12,16])
val b = map (hd, [[8,6],[7,5],[3,0,9]])
```

Programming Languages

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Advantages of Structs

Contrasting Approaches

```
(struct add (e1 e2) #:transparent)
```

Versus

```
(define (add e1 e2) (list 'add e1 e2))
(define (add? e) (eq? (car e) 'add))
(define (add-e1 e) (car (cdr e)))
(define (add-e2 e) (car (cdr (cdr e))))
```

This is *not* a case of syntactic sugar

The key difference

```
(struct add (e1 e2) #:transparent)
```

- The result of calling **`(add x y)`** is *not* a list
  - And there is no list for which **`add?`** returns **`#t`**

- **`struct`** makes a new kind of thing: extending Racket with a new kind of data

- So calling **`car`**, **`cdr`**, or **`mult-e1`** on “an add” is a run-time error

List approach is error-prone

```
(define (add e1 e2) (list 'add e1 e2))
(define (add? e) (eq? (car e) 'add))
(define (add-e1 e) (car (cdr e)))
(define (add-e2 e) (car (cdr (cdr e))))
```

- Can break abstraction by using **`car`**, **`cdr`**, and list-library functions directly on “add expressions”
  - Silent likely error:

```
(define xs (list (add (const 1)(const 4)) …))

(car (car xs))
```

- Can make data that **`add?`** wrongly answers **`#t`** to

```
(cons 'add "I am not an add")
```

Summary of advantages

Struct approach:

- Is better style and more concise for *defining* data types
- Is about equally convenient for *using* data types
- But much better at timely errors when *misusing* data types
  - Cannot accessor functions on wrong kind of data
  - Cannot confuse tester functions

More with abstraction

Struct approach is even better combined with other Racket features not discussed here:

- The *module system* lets us hide the constructor function to enforce invariants
  - List-approach cannot hide cons from clients
  - Dynamically-typed languages can have abstract types by letting modules define new types!

- The *contract system* lets us check invariants even if constructor is exposed
  - For example, fields of “an add” must also be “expressions”

Struct is special

Often we end up learning that some convenient feature could be coded up with other features

Not so with struct definitions:

- A function cannot introduce multiple bindings
- Neither functions nor macros can create a new kind of data
  - Result of constructor function returns **`#f`** for *every* other tester function: **`number?`**, **`pair?`**, other structs' tester functions, etc.