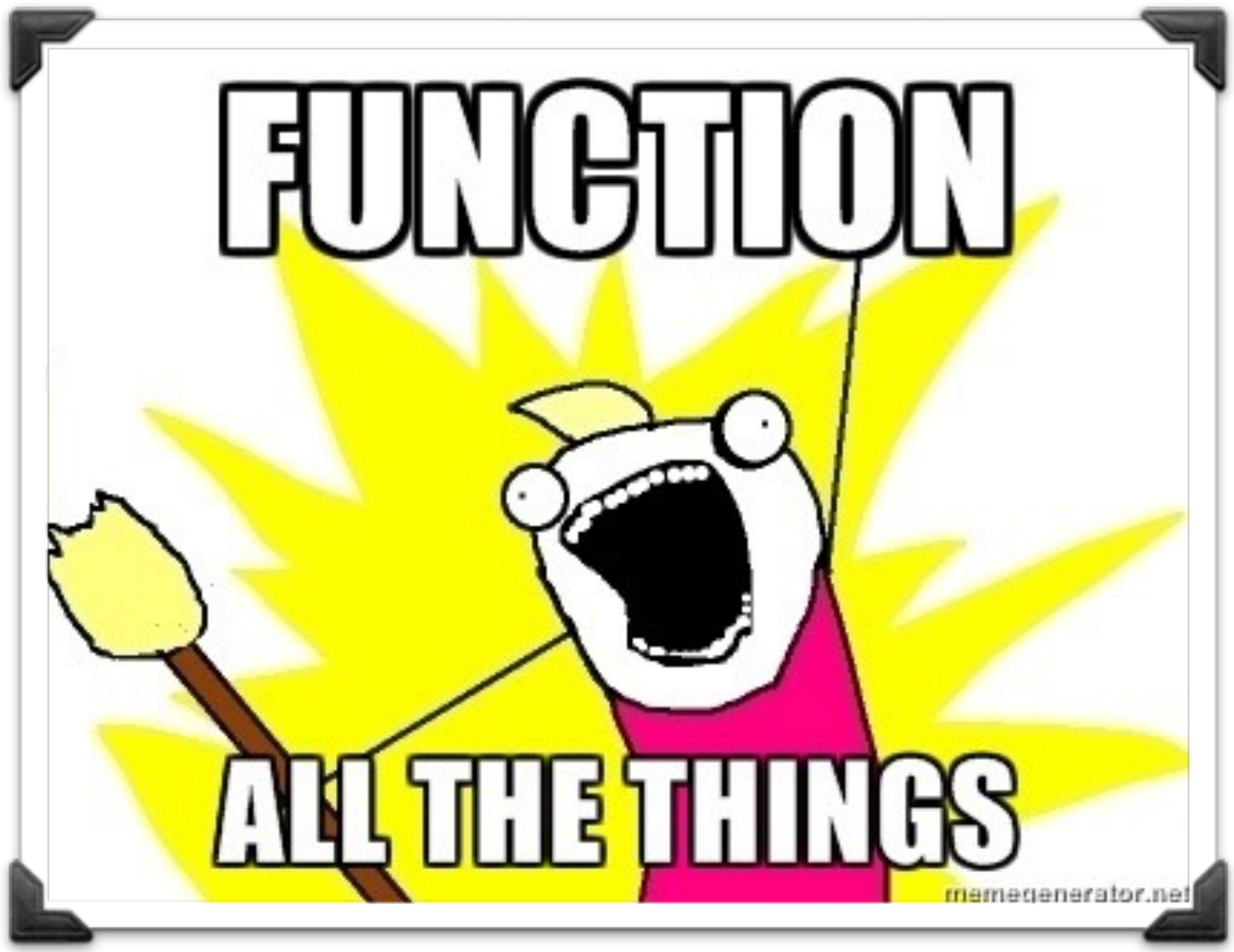
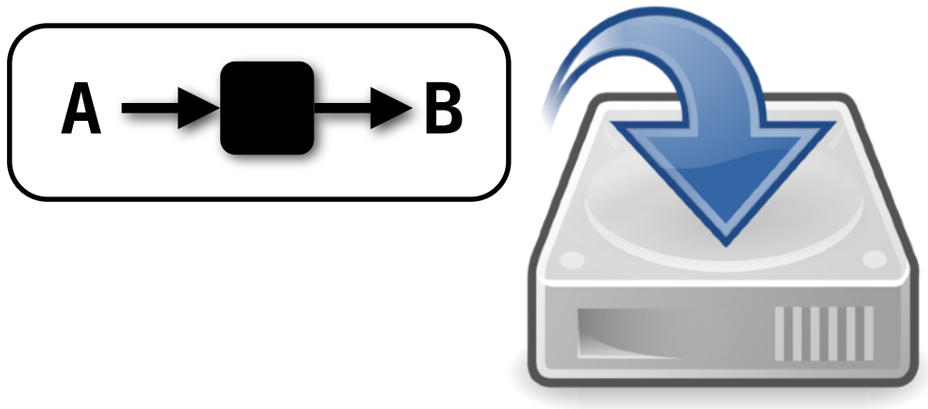
Higher-Order Data



Functions are data



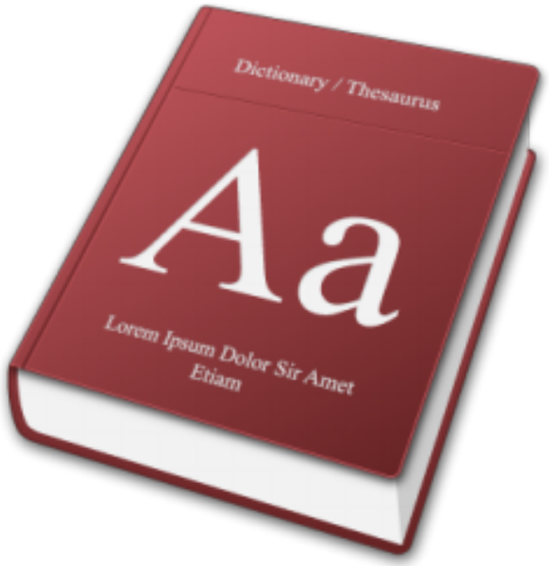
We can:

- pass functions as input — `map`, `filter`, `foldr`
- return functions as output — `(.)`, *partial application*
- write function literals — `\f -> f . f`
- **store functions in data types!**

```
data Expr
   = Lit Int
   | Ref Var
   | Bin (Int -> Int -> Int) Expr Expr
```

(BinOp.4.hs)

Dictionary pattern



Basic idea:

- **data type** describes an **interface**
- **values** represent **instances**

Can do "pure object-oriented programming" in Haskell!

(MonoidDict.hs, SetOO.hs)

Combinator pattern

Basic idea:

- **type** defines the **semantic domain** of a language
- **values** represent **semantic objects**
- **functions** define the **syntax** *"shallow embedding" of a DSL*

A <u>very</u> successful pattern in Haskell!

(Env.hs, Hasklet2.hs (Parsers))

Combinator pattern tradeoffs

Advantages:

- **easy to extend with new cases and operations**
- DSL that reuses features of host language
  e.g. bindings, type system
- high compositionality – leads to general, powerful designs

Disadvantages:

- **difficult to extend with new interpretations**
  e.g. pretty print a parser specification
- hard to analyze/manipulate internal structure of values
  e.g. optimize a parser

Higher-order abstract syntax pattern

A technique for implementing **name bindings** in ASTs

Basic idea:

- use **host language** (Haskell) bindings to encode **object language** bindings

A "shallow" feature in an otherwise "deep embedding"

Advantage: reuse features of host language

Disadvantages: hard to analyze/manipulate structure
e.g. optimize, get all variable names

(HOAS.hs)