CSCE 314 Reference Sheet © May 1, 2017 Josh Wright

General:

- `newtype Parser a = P (String -> [(a,String)])`
- Predicate: a function that takes one argument and returns a boolean
  - if `pred x == True` then `x` satisfies predicate `pred`
- function composition:

```
-- the . operator composes functions:
(f . g) x == f (g x)
```

useful library functions:

```
-- Data.List
nubBy :: (a -> a -> Bool) -> [a] -> [a]
nubBy pred xs = -- unique elements only from xs as
                -- determined by pred
nub :: Eq a => [a] -> [a]
nub xs = nubBy (==) a -- unique elements from xs
--
words :: String -> [String]
words xs =  -- list of whitespace-separated
            -- words from xs
--
-- concatenate container of lists
concat :: Foldable t => t [a] -> [a]
-- or for list-of-lists specifically:
concat :: [[a]] -> [a]
concat xs = foldl (++) [] xs
--
-- like concat, but use a function to get the inner lists
concatMap :: (a -> [b]) -> [a] -> [b]
concatMap f xs =  foldr ((++) . f) [] xs
--
-- get the longest prefix of xs for which pred is true
↪  and also return the rest of the list
span :: (a -> Bool) -> [a] -> ([a], [a])
span pred xs = (takeWhile pred xs, dropWhile pred xs)
--
-- repeat a = infinite list of a
repeat :: a -> [a]
repeat x = map (\_ -> x) [1..]
repeat x = [ x | _ <- [1..] ]
-- replicate n a = list of length n repeating a
replicate :: Int -> a -> [a]
replicate n x = map (\_ -> x) [1..n]
replicate n x = [ x | _ <- [1..n] ]
--
-- folds (works on any foldable, not just lists)
foldr :: (a -> b -> b) -> b -> [a] -> b
foldr f z [a,b,c] = a `f` (b `f`  (c `f` z))
foldr f z [a,b,c] = f a $ f b $ f c z
-- combines into z from right to left
-- can potentially work on an empty list if one of the
↪  folds does not evaluate it's second argument
foldl :: (b -> a -> b) -> b -> [a] -> b
foldl f z [a,b,c] = ((z `f` a)  `f` b)  `f` c
foldl f z [a,b,c] = f (f (f z a) b) c
-- evaluates from right to left
-- will not work on infinite list because it must start
↪  at the end of the list
--
-- these are the same as above, except they take the
↪  first two elements for the first application of f
foldr1 :: (a -> a -> a) -> [a] -> a
foldl1 :: (a -> a -> a) -> [a] -> a
```

Parsing.hs:

- `sat :: (Char -> Bool) -> Parser Char`
  - returns a character if that character satisfies the predicate
- `digit, letter, alphanum :: Parser Char`
  - parses a digit, letter, or alpha-numeric letter respectively
- `char :: Char -> Parser Char`
  - `char 'a'` parses exactly the character `'a'`
- `item :: Parser Char`
  - parses any character
- similar to above: `digit letter alphanum lower upper string`
- `many :: Parser a -> Parser [a]`
  - parses 0 or more instances of `a` and collects them into a list
- `many1 :: Parser a -> Parser [a]`
  - same as `many`, but
- `(+++)` choice:
  - parse first argument if possible, else parse second argument
  - first successfully parsed argument is returned

```
(+++) :: Parser a -> Parser a -> Parser a
p +++ q =  P (\inp -> case parse p inp of
                  []         -> parse q inp
                  [(v,out)]  -> [(v,out)])
```

- `((>>=))` sequential composition
  - `a >>= b` unboxes monad `a` into an output `a0` and then unboxes monad `b` with input `a0`

```
type Parser a = String -> [(a, String)]
-- implementation for in-class mostly-complete parser
↪  `monads'
(>>=) :: Parser a -> (a -> Parser b) -> Parser b
(>>=) p1 p2 = \inp -> case parse p1 inp of
      []  ->  []
      [(v, out)] -> parse (p2 v) out
```

  - usage:

```
doubleDigit :: Parser [Char]
doubleDigit =
  digit >>= \a ->
  digit >>= \b ->
  return [a,b]
-- is equivalent to
doubleDigit' :: Parser [Char]
doubleDigit' = do
  a <- digit
  b <- digit
  return [a,b]
```

  - `(>>)` is the same except that it discards the result of the first monad (thus it has signature `(>>) :: Parser a -> Parser b -> Parser b`)

Parsing Examples:

- bind and lambda method of parsing:
  - parse a number:
- parse arithmetic expressions using do syntax:

```
expr :: Parser Int
expr  = do t <- term
           do {char '+'
              ;e <- expr
              ;return (t + e)
              }
            +++ return t

term :: Parser Int
term  = do f <- factor
           do char '*'
              t <- term
              return (f * t)
            +++ return f

factor :: Parser Int
factor  = do d <- digit
             return (digitToInt d)
           +++ do char '('
                  e <- expr
                  char ')'
                  return e

eval   :: String -> Int
eval xs = fst (head (parse expr xs))
```

Trees:

- represent either a leaf node or some kind of internal node
- arithmetic tree declaration:

```
data Expr = Val Int
          | Neg Expr
          | Add Expr Expr
          | Mul Expr Expr
```

- how to fold over a tree:

```
-- exprFold  valF        negF      addF
exprFold :: (Int->b) -> (b->b) -> (b->b->b) ->
-- mulF         input   output
  (b->b->b) -> Expr -> b
exprFold valF _ _ _ (Val i) = valF i
exprFold valF negF addF mulF (Neg e)
  = negF  (exprFold valF negF addF mulF e)
exprFold valF negF addF mulF (Add s1 s2)
  = addF  (exprFold valF negF addF mulF s1)
          (exprFold valF negF addF mulF s2)
exprFold valF negF addF mulF (Mul s1 s2)
  = mulF  (exprFold valF negF addF mulF s1)
          (exprFold valF negF addF mulF s2)
```

* basically, just collect values into some type `b` and use supplied functions at each node to fold into single value
* useful for evaluating simple things like:

```
-- evaluate an expression
evalExpr'    = exprFold id (\x -> 0 - x) (+) (*)
id --  integers map to integers
(\x -> 0 - x) -- negation
-- everything else is just simple numeric operators
--
-- count leaves in a tree
countLeaves' = exprFold (\_ -> 1) id (+) (+)
(\_ -> 1) -- leaf integer node is one node
id -- negation node has only one child, pass on count
(+) (+) -- nodes with two children: add number of leaf
 ↪  grandchildren
```

HW2: Water Gates:

```
waterGate :: Int -> Int
waterGate n =
 length -- number of True's
 $ filter id -- filter just True's
 $ waterGate' n initial -- initial call to helper
 where
  -- start with all gates closed
  initial = replicate n False
  --
  -- flip states
  waterGate' 1 state = map not state
    -- base case: flip every state
  waterGate' n state = flip n $ waterGate' (n-1) state
  -- otherwise, first get the state for (n-1) and then
↪  flip every nth state
  --
  -- flip every nth gate
  flip :: Int -> [Bool] -> [Bool]
  flip 1 xs = map not xs -- flip every gate
  -- flip only gates which index are multiples of n
  flip nth xs = [ if (i `mod` nth == 0) then not x else x
                -- zip each state with it's index
                | (x,i) <- (zip xs [1..])  ]
```

HW2: Goldbach's Other Conjecture:

```
-- check if a number is prime
primeTest :: Integer -> Bool
primeTest 1 = False
primeTest t =  and [ (gcd t i) == 1 | i <- [2..t-1]]

-- all numbers less than n that are double a square
twiceSquares :: Integer -> [Integer]
twiceSquares n = takeWhile (<n) [ 2 *x^2 | x <- [1..]]

-- list of odd numbers
oddList = map (\x -> 2*x + 1) [0..]
-- all odd numbers that are composite (not prime)
allOddComp = [ o | o <- (drop 1 oddList)
                 , not (primeTest o)     ]

-- if a number satisfies conditions for conjecture
-- method: for enough square nubmers, check if n-(that
 ↪  number) is prime
satsConds n = or [ primeTest k |
                  k <- map (\x->(n-x)) (twiceSquares n) ]

-- find the first number
goldbachNum = head [ x | x <- allOddComp
                       , not (satsConds x) ]
```

HW4: Sets:

```
type Set a = [a]

a = mkSet [1,2,3,4,5]
b = mkSet [1,2,3]


addToSet :: Eq a => Set a -> a -> Set a
addToSet s a | a `elem` s = s
             | otherwise = a : s

mkSet :: Eq a => [a] -> Set a
mkSet lst = foldl addToSet [] lst

isInSet :: Eq a => Set a -> a -> Bool
isInSet [] _ = False
isInSet [a] b = a == b
isInSet (x:xs) b | x == b = True
                 | otherwise = isInSet xs b

subset :: Eq a => Set a -> Set a -> Bool
subset sub super = and [ isInSet super x | x <- sub  ]

setEqual :: Eq a => Set a -> Set a -> Bool
setEqual a b = subset a b && subset b a

-- instance (Eq a) => Eq (Set a) where
--   a == b = subset a b && subset b a

setProd :: Set a -> Set a -> [(a,a)]
setProd a b = [ (ai,bj) | ai <- a
                        , bj <- b
                        ]
```

Prev Exam: Run Length Encoding:

```
import Parsing
import Data.Char

q4 = do
  d <- sat isUpper
  e <- char (toLower d)
  f <- many item
  return [d,e]

ones = (map (\_ -> 1) [1..])

myRLE [] = []
myRLE ls = myhelper (zip ones ls)

myhelper [(n,c)] =  [(n,c)]
myhelper ((n,c):(m,d):rest)
  | (d == c)  = myhelper (((n+m),c):rest)
  | otherwise = (n,c):myhelper ((m,d):rest)
```

Rock Paper Scissors:

```
data RPS = Rock | Paper | Scissors
  deriving (Eq, Show)

rps :: RPS -> RPS -> Int
rps a b | a == b = 0
rps Rock     Scissors = 1
rps Paper    Rock     = 1
rps Scissors Paper    = 1
rps _        _        = 2

rps2 :: RPS -> RPS -> Int
rps2 a b =
  if a == b then 0 else case (a,b) of
    (Rock,     Scissors) -> 1
    (Paper,    Rock)     -> 1
    (Scissors, Paper)    -> 1
    _ -> 2
```

99 problems:

```
-- 9. pack consecutive duplicates into sublists
pack (x:xs) = let (first,rest) = span (==x) xs
               in (x:first) : pack rest
pack [] = []
-- example:
pack [1,2,3,2,2,3] == [[1,1],[2],[3],[2,2],[3]]
```

Java:

- **Class Invariant**: A logical condition that ensures that an object of a class is in a well-defined state.
  * public methods assume that invariant holds before it's called, and makes sure to preserve the invariant property
- garbage collection deals only with memory. You must manage other resources manually, such as concurrent locks, OS file handles, etc...
- anonymous classes are a thing
- inner class: class declared inside another class implicitly holds a reference to it's outer class.
  This means instances of the inner class can use non-static fields/methods of the outer class.
  This is especially handy for callbacks e.g. on android

Inheritance and Virtual Methods:

- Java classes can inherit from one class only
  * inheritance: `class ChildClass extends ParentClass`

- child class gets access to public fields/methods (of course) and protected fields/methods
- child class does not get access to private fields/methods
- TODO abstract classes/methods

- interfaces: `class MultiPurpose implements Interface1, IFace2...`
  - basically an end around lack of multiple inheritance
  - interfaces cannot be instantiated, but you can have a reference of interface type. In that case, the object it points to is a real concrete class, but all that you know about it is that it implements the specified interface
- virtual dispatch:
  - all public non-static class methods are virtual. This means that if a subclass overrides a parent class method, the decision of which method implementation to use is made at runtime, depending on which type of object the reference actually refers to.
  - all interface methods are by definition virtual
  - private methods are not virtual, static methods are not virtual
- notable interfaces:
  - `Iterable<T>`: contains `Iterator<T> iterator()` method, to iterate over container
  - `Iterator<E>`: encapsulates an iteration over a container. Unlike C++ iterators, this iterator knows when it's reached the end, instead of relying on comparison to a one-past-end iterator
    - `boolean hasNext()`: ask if we're at the end
    - `E next()`: retrieve next element, and advance iterator
  - `Runnable`: single `void run()` method. This is the interface that threads use

Generics:

- TODO

```java
import java.lang.*;
class GenericWildcards {
  // T is the binding of the generic parameter
  private static class GenericBox<T> {
    // it is optional, but we need it if we want to do things with that type
    public T t;
    public GenericBox(T t) { this.t = t; }
  }
  private static class NumberBox<T extends Number> {
    public T t;
    public NumberBox(T t) { this.t = t; }
  }
  public static void printBox(GenericBox<?> b) {
    // here we use the ? wildcard with no type binding because we don't need to do things with that type specifically
    System.out.println(b.t);
  }
  // method generic goes before return type
  public static <T> void printWithParameter(GenericBox<T> b) {
    System.out.println(b.t);
  }
  public static void main(String[] args) {
    // this is using raw types, generally considered bad
    GenericBox rawBox = new GenericBox("asdf1"); // compiler warnings
    // this cast is ok because raw types hold java.lang.Object
    Object o1 = rawBox.t;
    // this causes no warnings for same reason as assignment above doesn't
    printBox(rawBox);

    // this is just using an unknown type, java says it's fine
    GenericBox<?> unknownBox = new GenericBox<>("asdf2");
    // this is also OK because <?> explicitly makes the generic parameter as java.lang.Object
    Object o2 = unknownBox.t;
    printBox(unknownBox);

    GenericBox<String> stringBox = new GenericBox<>("asdf3");
    // the type parameter above allows Java to infer that this cast is safe
    String s = stringBox.t;
    System.out.println(s);
    // must specify type between class access and method name (works the same for instance methods too)
    GenericWildcards.<String>printWithParameter(stringBox);

    // correct stuff works like expected
    NumberBox<Integer> nb1 = new NumberBox<>(5);
    System.out.println(nb1.t + 1);
    //
    // this will fail to even allow NumberBox<String> because that type doesn't work
    // NumberBox<String> sb1 = new NumberBox<>("asdf");
    //
    // this will fail because the inferred type of NumberBox<>("asdf") is NumberBox<String>, which isn't allowed
    // NumberBox<?> sb1 = new NumberBox<>("asdf");
  }
}
```

Locks: `ReentrantLock` and `Condition`:

`import java.util.concurrent.locks.ReentrantLock;`

`import java.util.concurrent.locks.Condition;`

`ReentrantLock`:

- `ReentrantLock`: basically a mutex
- `ReentrantLock.lock()`: acquire the lock (blocking)
  - does **not** throw `InterruptedException`
- `ReentrantLock.unlock()`: release the lock
  - does **not** throw `InterruptedException`
  - you should always wrap your locking code in a `try{}` block (including the call to `lock()` itself) and put the call to `unlock()` in a `finally{}` block.

    This way, `unlock()` gets called no matter any exception

`Condition`:

- created from a lock, allows one thread to send a message to another thread
  - create form lock instance using `lock.newCondition()`
- `await()`: release this lock and wait for the condition to be signaled.

  When the signal happens, `await()` will automatically re-acquire the lock before returning

  (this means you will still have to unlock manually)
  - you can only `await()` when you are holding the lock, and when it returns, you still have the lock, so it acts like you never unlocked it
  - **does** throw `InterruptedException`
- `signal()`: wake up a single thread that is waiting on the condition
  - must be holding lock to signal it's condition
  - must manually release lock before other thread will return from `await()` (because the other thread must also acquire the lock)
  - does **not** throw `InterruptedException`
- `signalAll()`: similar to `signal()` except that every thread is woken up
  - still only one thread will be able to use the lock-protected resource at a time, because locks
  - does **not** throw `InterruptedException`

```java
import java.lang.*;
import java.util.concurrent.locks.ReentrantLock;
import java.util.concurrent.locks.Condition;
public class Main2 {
  public static class Counter {
    public int count = 0;
    public ReentrantLock lock;
    public Condition updated;
    public Counter() {
      this.lock = new ReentrantLock();
      this.updated = lock.newCondition();
    }
  }
  public static class CounterThread implements Runnable {
    private Counter counter;
```

```java
    public CounterThread(Counter c) {counter = c;}
    @Override
    public void run() {
      while (true) {
        try {
          counter.lock.lock();
          counter.count += 1;
          System.out.println(counter.count);
          counter.updated.signalAll();
        }
        // lock() does not throw InterruptedException
        // catch (InterruptedException e) {}
        finally {counter.lock.unlock();}

        try {
          Thread.sleep(1000);
        } catch (InterruptedException e) {}
      }
    }
  }

  public static class IntervalPrinter implements Runnable
↪  {
    private Counter counter;
    private int mod;
    private String message;
    public IntervalPrinter(Counter c, int mod, String
↪  msg) {
      counter = c;
      this.mod = mod;
      message = msg;
    }
    @Override
    public void run() {
      while (true) {
        int val = 0;
        try {
          counter.lock.lock();
          counter.updated.await();
          val = counter.count;
        }
        catch (InterruptedException e) {}
        finally {counter.lock.unlock();}

        if (val % mod == 0) {
          System.out.println(message);
        }
      }
    }
  }

  public static void main(String []args) {
    Counter c = new Counter();
    new Thread(new IntervalPrinter(c,3,"fizz")).start();
    new Thread(new IntervalPrinter(c,5,"buzz")).start();
    new Thread(new CounterThread(c)).start();
  }
}
```

Reflection:

`java.lang.Class<T>`:

- allows you to reflect on class `T`
- `toString()` returns class declaration (more or less)
- `getSimpleName()` returns just the name part of it
  - `Main.class.getSimpleName()` → `"Main"`
- to get:
  - `Class<?> c = SomeClassName.class;`
  - `Class<?> c = someObjectInstance.getClass();`
  - `Class<?> c = Class.forName("SomeClassName");`
    - throws `ClassNotFoundException`
- `Method[] getMethods()`
  - all public member methods, including those inherited from super-classes and implemented in interfaces
- `Method[] getDeclaredMethods()`
  - excludes inherited methods, includes any that are declared in class regardless of public, private, static, etc...
- `Constructor<T> getConstructor(Class<?>... pt)`
  - get a constructor for `T` that matches parameter types `Class<?>... pt`
  - throws `NoSuchMethodException` if there is no constructor matching those parameter types
- `T newInstance()`
  - create a new instance of `T` using the default constructor
- TODO use `Constructor` class to create class using non-default constructor
- TODO fields

`java.lang.reflect.Method`:

- `String toString()` → method prototype as string
  - includes modifiers, method name, parameters, etc...
- `String getName()` → name of method as string
- `int getModifiers()` → `int` representing modifiers
  - use `java.lang.reflect.Modifier` static methods to check: `Modifier.isStatic(m.getModifiers())`
- `Class<?>[] getParameterTypes()` → types of parameters of method
  - if no parameters, returns empty array
  - does not include implicit `this` parameter for instance methods
- `Type[] getGenericParameterTypes()`: same, but returns a `Type` instance that accurately represents the generic info from the actual source
- `Class<?> getReturnType()`: get the return type
  - if it's void, it returns a void type
- `Object invoke(Object obj, Object... args)`
  - invoke a method on an object. Subject to virtual method lookup
  - if the method is static, `obj` may be null
  - if the method returns a primitive type, it is wrapped; if void, returns null
  - throws `IllegalAccessException` if you can't run that method because it's private or something
  - if target method throws, it throws `InvocationTargetException` wrapping whatever was thrown