ThoughtWorks®

Functional Thinking

NEAL FORD software architect / meme wrangler

ThoughtWorks®

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NF

tortured

3 ^ metaphors

assign to x

$$x := x + 1$$

solve for x?

Paradigms

~~Languages~~ are tools.

Learning a new one takes time.

"functional" is more a way of thinking than a tool set

Execution in the Kingdom of Nouns

Steve Yegge

http://steve-yegge.blogspot.com/2006/03/execution-in-kingdom-of-nouns.html

v e r b s !

"OOP makes working with state easier.

FP makes eliminating state easier"

OH on twitter

OO makes code understandable by encapsulating moving parts.

FP makes code understandable by minimizing moving parts.

Michael Feathers, author of “Working with Legacy Code”

number classification

perfect

$$\Sigma(f(\#)) - \# = \#$$

(sum of the factors of a #) - # = #

(sum of the factors of a #) = 2#

6: 1 + 2 + 3 + 6 = 12 (2x6)

28: 1 + 2 + 4 + 7 + 14 + 28 = 56 (2x28)

496: . . .

classification

$\Sigma(f(\#)) = 2\#$ perfect

$\Sigma(f(\#)) > 2\#$ abundant

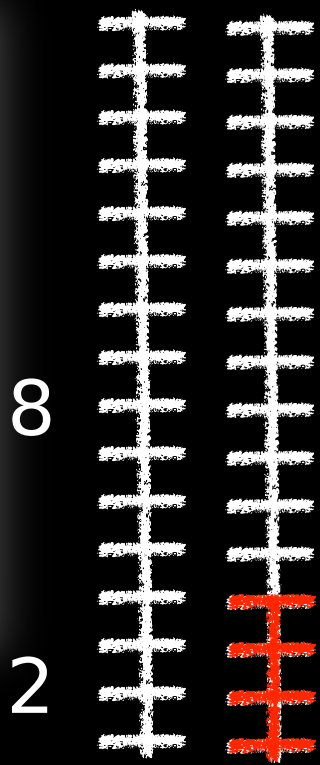
$\Sigma(f(\#)) < 2\#$ deficient

imperative

```java
public class Classifier6 {
    private Set<Integer> _factors;
    private int _number;

    public Classifier6(int number) {
        if (number < 1)
            throw new InvalidNumberException(
            "Can't classify negative numbers");
        _number = number;
        _factors = new HashSet<Integer>();
        _factors.add(1);
        _factors.add(_number);
    }

    public boolean isPerfect() {…

    public boolean isAbundant() {…

    public boolean isDeficient() {…

    public static boolean isPerfect(int number) {…
}
```

```java
public class Classifier6 {
    private Set<Integer> _factors;
    private int _number;

    public Classifier6(int number) {…

    private boolean isFactor(int factor) {
        return _number % factor == 0;
    }

    public Set<Integer> getFactors() {
        return _factors;
    }

    public boolean isPerfect() {…

    public boolean isAbundant() {…

    public boolean isDeficient() {…

    public static boolean isPerfect(int number) {…
}
```

```java
public class Classifier6 {
    private Set<Integer> _factors;
    private int _number;

    public Classifier6(int number) {...

    private boolean isFactor(int factor) {...

    public Set<Integer> getFactors() {...

    private void calculateFactors() {
        for (int i = 2; i < sqrt(_number) + 1; i++)
            if (isFactor(i))
                addFactor(i);
    }

    private void addFactor(int factor) {
        _factors.add(factor);
        _factors.add(_number / factor);
    }
}
```



```java
public class Classifier6 {
    private Set<Integer> _factors;
    private int _number;

    public Classifier6(int number) {…

    private boolean isFactor(int factor) {…

    public Set<Integer> getFactors() {…

    private void calculateFactors() {…

    private void addFactor(int factor) {…

    private int sumOfFactors() {
        calculateFactors();
        int sum = 0;
        for (int i : _factors)
            sum += i;
        return sum;
    }
}
```

```java
public class Classifier6 {
    private Set<Integer> _factors;
    private int _number;

    public Classifier6(int number) {…

    private boolean isFactor(int factor) {…

    public Set<Integer> getFactors() {…

    private void calculateFactors() {…

    privat

    privat

    public

    public

    public

    public
}
```

```java
public boolean isPerfect() {
    return sumOfFactors() - _number == _number;
}

public boolean isAbundant() {
    return sumOfFactors() - _number > _number;
}

public boolean isDeficient() {
    return sumOfFactors() - _number < _number;
}
```

```
public class Classifier6 {
    private Set<Integer> _factors;
    private int _number;

    public Classifier6(int number) {…

    private boolean isFactor(int factor) {…

    public Set<Integer> getFactors() {…

    private void calculateFactors() {…

    private void addFactor(int factor) {…

    private int sumOfFactors() {…

    public boolean isPerfect() {…

    public boolean isAbundant() {…

    public boolean isDeficient() {…

    public static boolean isPerfect(int number) {…
}
```

internal state

cohesive

composed

testable

refactorable

(slightly more) functional

```java
public class NumberClassifier {

    public boolean isFactor(int number, int potential_factor) {
        return number % potential_factor == 0;
    }
    public int sum(Set<Integer> factors) {…

    public boolean isPerfect(int number) {…

    public boolean isAbundant(int number) {…

    public boolean isDeficient(int number) {…
}
```

```java
public class NumberClassifier {

    public boolean isFactor(int number, int potential_factor) {…

    public Set<Integer> factors(int number) {
        HashSet<Integer> factors = new HashSet<Integer>();
        for (int i = 1; i <= sqrt(number); i++)
            if (isFactor(number, i)) {
                factors.add(i);
                factors.add(number / i);
            }
        return factors;
    }
}
```

```java
public class NumberClassifier {

    public boolean isFactor(int number, int potential_factor) {...

    public Set<Integer> factors(int number) {...

    public int sum(Set<Integer> factors) {
        Iterator it = factors.iterator();
        int sum = 0;
        while (it.hasNext())
            sum += (Integer) it.next();
        return sum;
    }
}
```

```java
public class NumberClassifier {

    public boolean isFactor(int number, int potential_factor) {⋯

    public Set<Integer> factors(int number) {⋯

    pub

    pub

    pub

    pub
}
```

```java
public boolean isPerfect(int number) {
    return sum(factors(number)) - number == number;
}

public boolean isAbundant(int number) {
    return sum(factors(number)) - number > number;
}

public boolean isDeficient(int number) {
    return sum(factors(number)) - number < number;
}
```

no internal state

```java
public class NumberClassifier {

    static public boolean isFactor(int number, int potential_factor) {…

    static public Set<Integer> factors(int number) {…

    static public int sum(Set<Integer> factors) {…

    static public boolean isPerfect(int number) {…

    static public boolean isAbundant(int number) {…

    static public boolean isDeficient(int number) {…
}
```

less need for scoping   refactorable   testable "functional" is more a way of thinking than a tool set

1st class functions

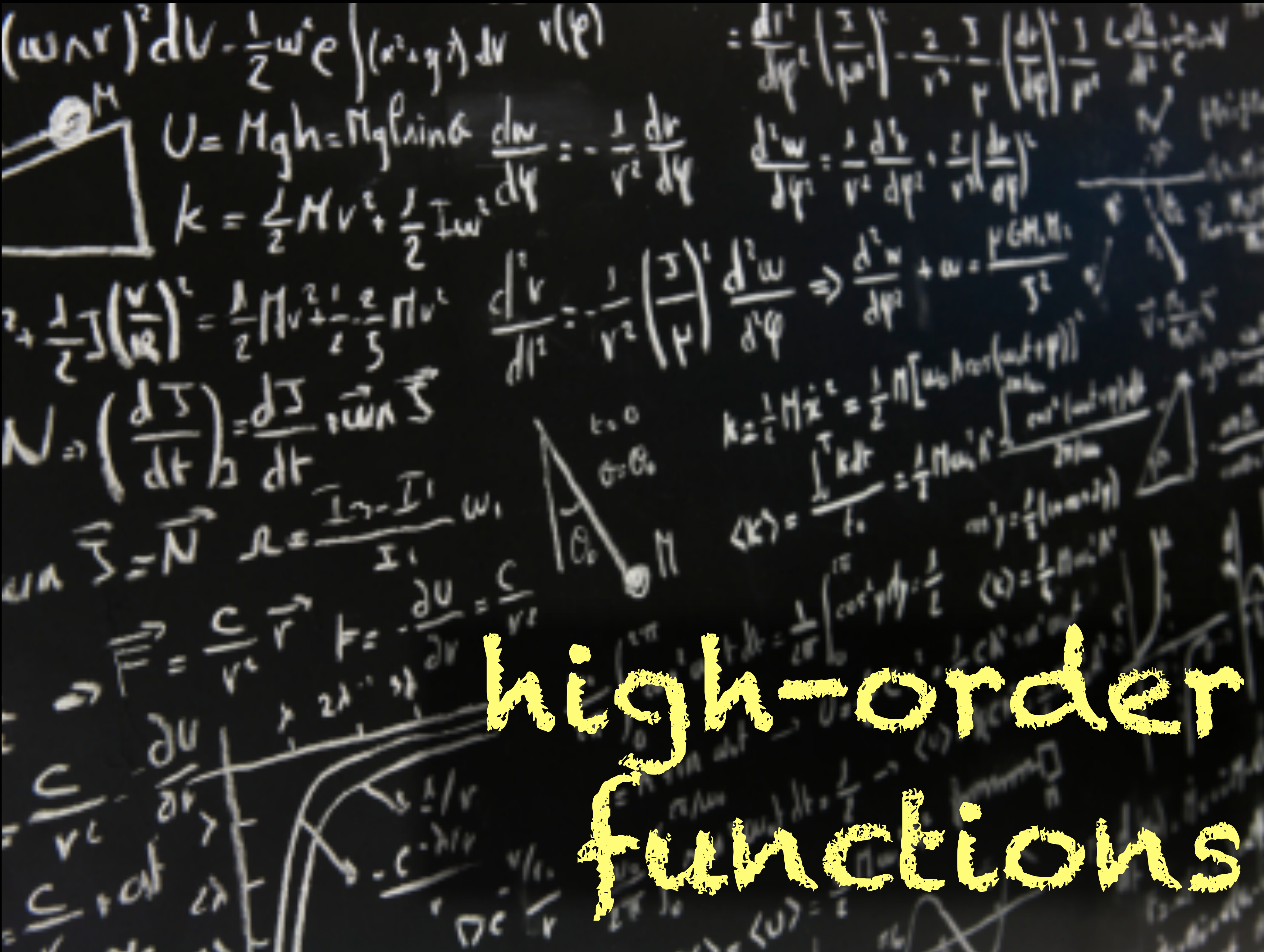
pure functions

concepts

strict evaluation

high-order functions

recursion



high-order functions

high-order functions

functions that can either take other functions as arguments or return them as results

```java
public void addOrderFrom(ShoppingCart cart, String userName,
                         Order order) throws Exception {
    setupDataInfrastructure();
    try {
        add(order, userKeyBasedOn(userName));
        addLineItemsFrom(cart, order.getOrderKey());
        completeTransaction();
    } catch (Exception condition) {
        rollbackTransaction();
        throw condition;
    } finally {
        cleanUp();
    }
}
```

```java
public void wrapInTransaction(Command c) throws Exception {
    setupDataInfrastructure();
    try {
        c.execute();
        completeTransaction();
    } catch (Exception condition) {
        rollbackTransaction();
        throw condition;
    } finally {
        cleanUp();
    }
}

public void addOrderFrom(final ShoppingCart cart,
    final String userName, final Order order) {
    wrapInTransaction(new Command() {
        public void execute() {
            add(order, userKeyBasedOn(userName));
            addLineItemsFrom(cart, order.getOrderKey());
        }
    });
}
```

```groovy
def wrapInTransaction(command) {
  setupDataInfrastructure()
  try {
    command()
    completeTransaction()
  } catch (Exception ex) {
    rollbackTransaction()
    throw ex
  } finally {
    cleanUp()
  }
}

def addOrderFrom(cart, userName, order) {
  wrapInTransaction {
    add order, userKeyBasedOn(userName)
    addLineItemsFrom cart, order.getOrderKey()
  }
}
```

```
UndoManager.execute()

undo() !
```

```
def addOrderFrom(cart, userName, order) {
  wrapInTransaction {
    add order, userKeyBasedOn(userName)
    addLineItemsFrom cart, order.getOrderKey()
  }
}
```

What's so special about...

closures

```groovy
def makeCounter() {
    def very_local_variable = 0
    return { very_local_variable += 1 }
}

c1 = makeCounter()
c1()
c1()
c1()

c2 = makeCounter()

println "C1 = ${c1()}, C2 = ${c2()}"
```

```
closures » groovy MakeCounter.groovy
C1 = 4, C2 = 1
```

```java
public class Counter {
    public int varField;

    public Counter(int var) {
        varField = var;
    }

    public static Counter makeCounter() {
        return new Counter(0);
    }

    public int execute() {
        return ++varField;
    }
}
```

let the <u>language</u> manage state

languages handle

memory allocation

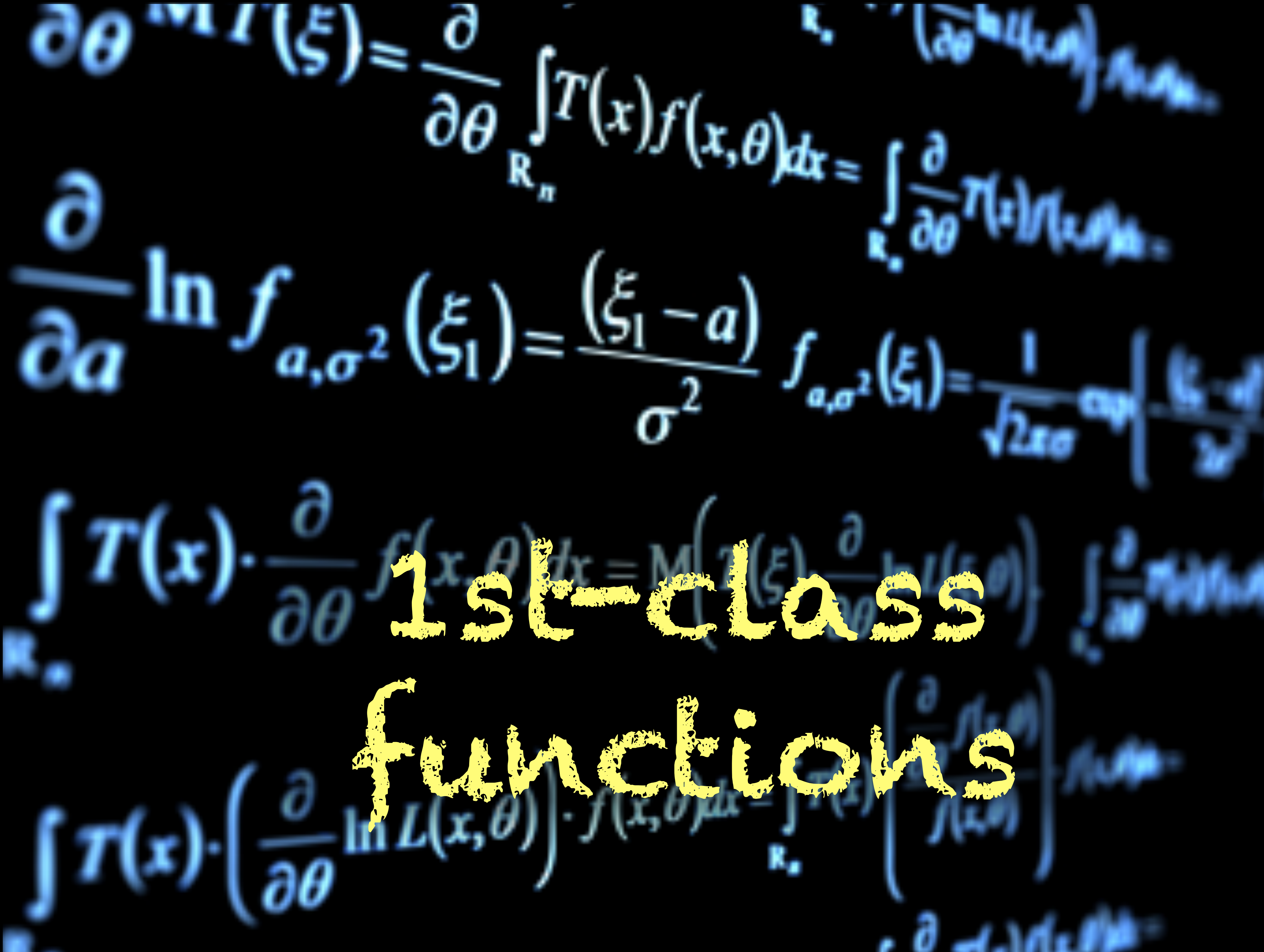
garbage collection

concurrency

state

tests → specification-based testing frameworks

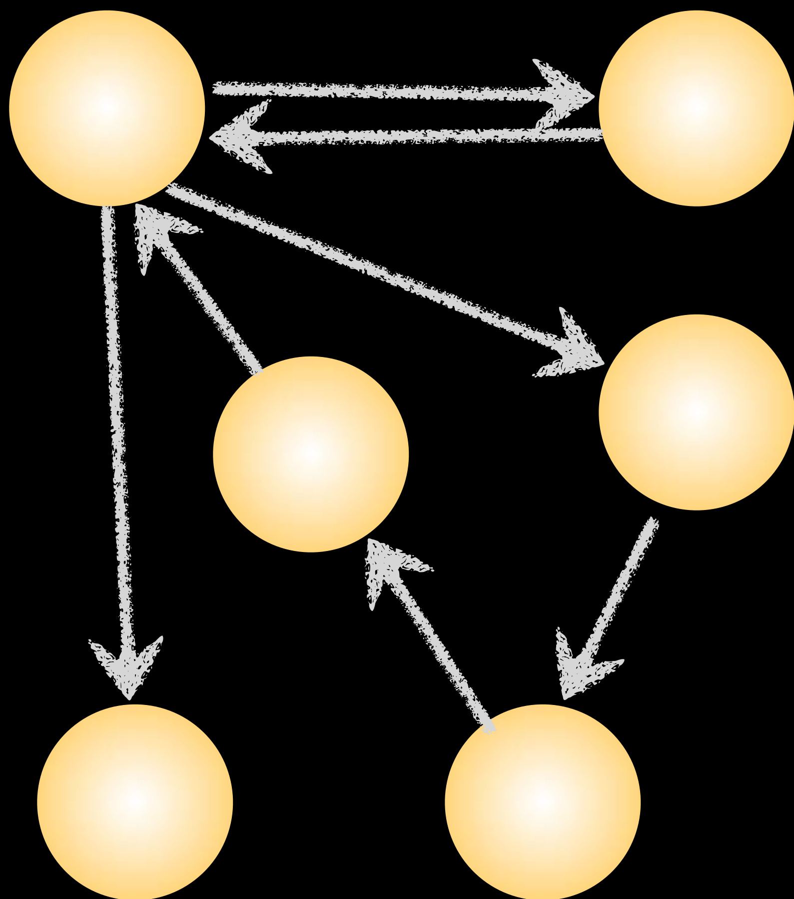
time

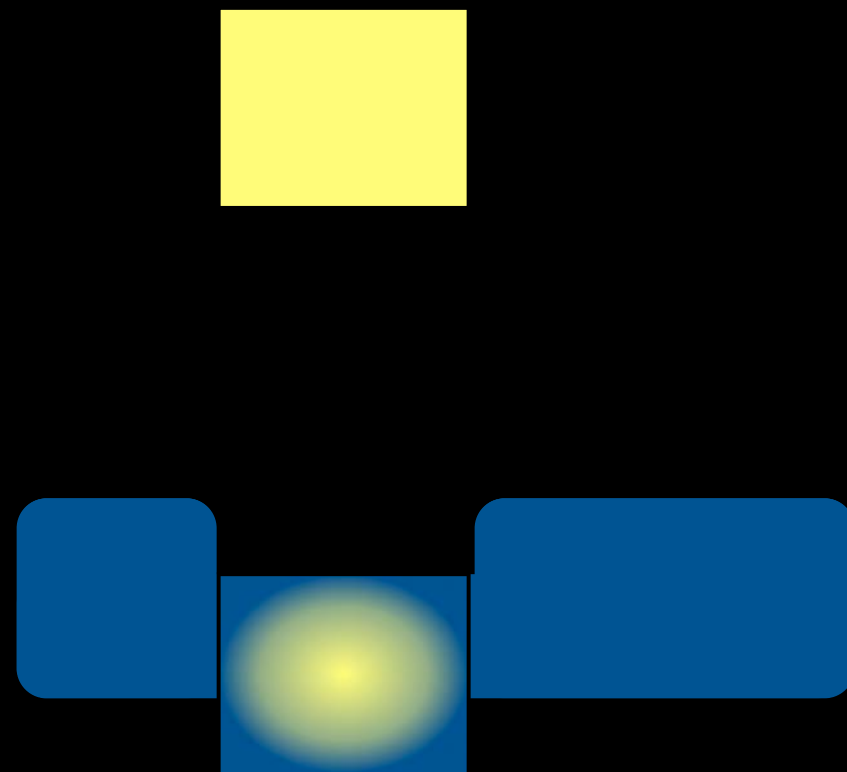


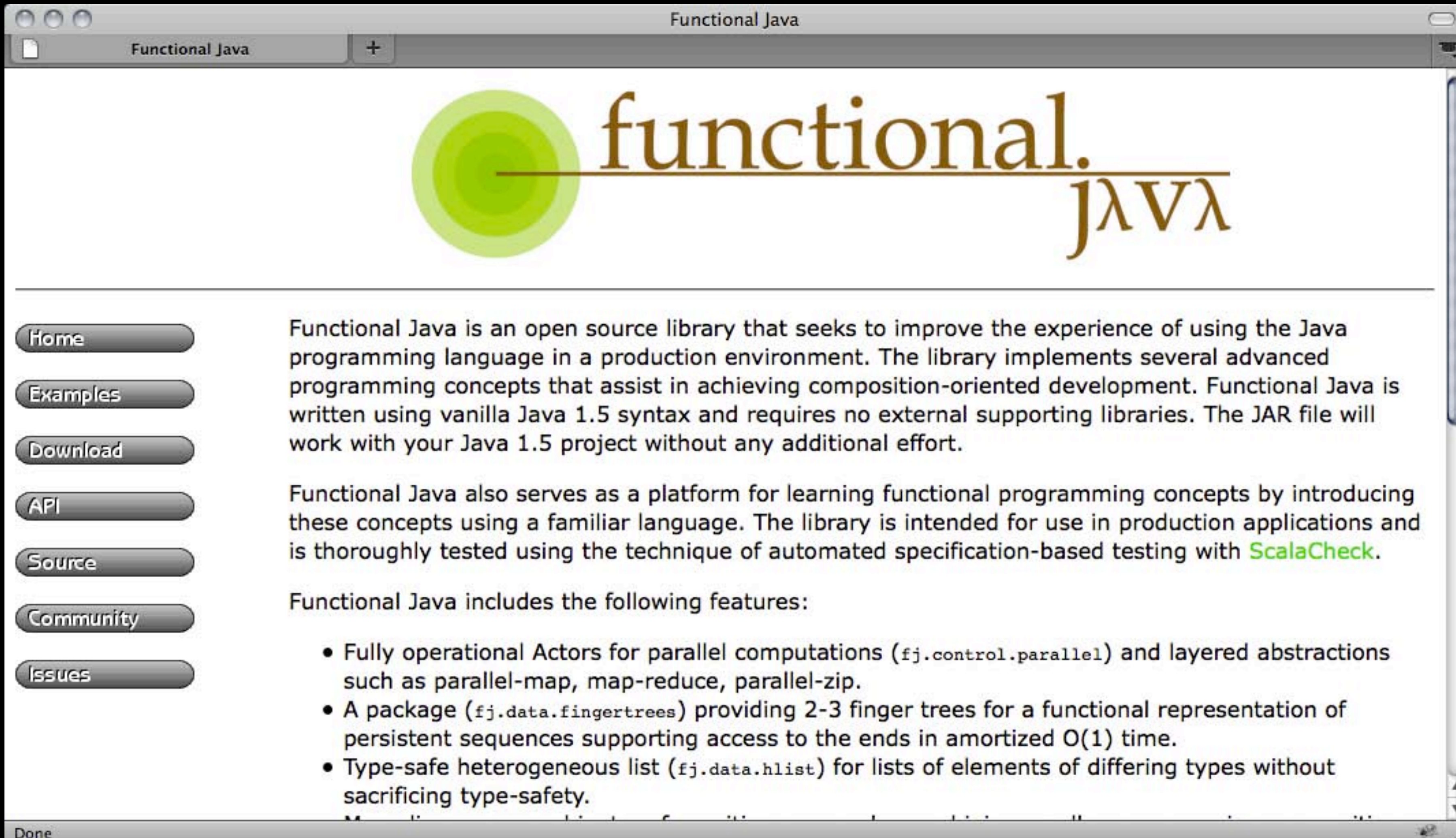
1st-class functions

1st-class functions

functions can appear anywhere other language constructs can appear






Functional Java
Functional Java
functional.
jλvλ
Home
Examples
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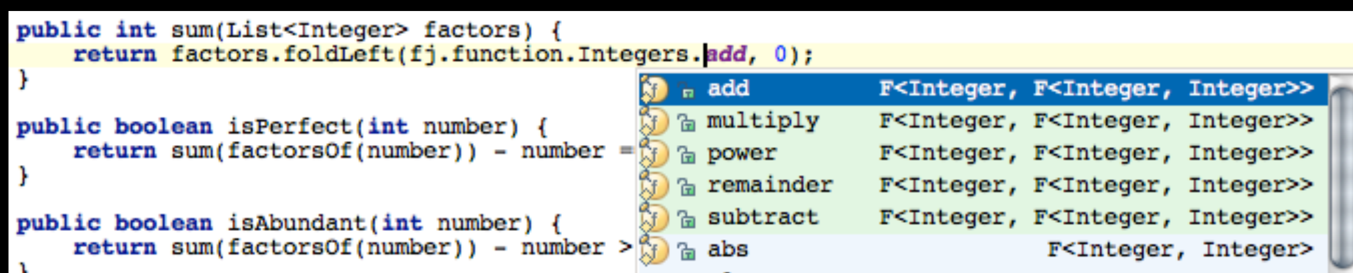
API
Source
Community
Issues
Functional Java is an open source library that seeks to improve the experience of using the Java programming language in a production environment. The library implements several advanced programming concepts that assist in achieving composition-oriented development. Functional Java is written using vanilla Java 1.5 syntax and requires no external supporting libraries. The JAR file will work with your Java 1.5 project without any additional effort.
Functional Java also serves as a platform for learning functional programming concepts by introducing these concepts using a familiar language. The library is intended for use in production applications and is thoroughly tested using the technique of automated specification-based testing with ScalaCheck.
Functional Java includes the following features:
• Fully operational Actors for parallel computations (fj.control.parallel) and layered abstractions such as parallel-map, map-reduce, parallel-zip.
• A package (fj.data.fingertrees) providing 2-3 finger trees for a functional representation of persistent sequences supporting access to the ends in amortized O(1) time.
• Type-safe heterogeneous list (fj.data.hlist) for lists of elements of differing types without sacrificing type-safety.
Done

```java
public class FNumberClassifier {

    public boolean isFactor(int number, int potential_factor) {
        return number % potential_factor == 0;
    }

    public List<Integer> factorsOf(final int number) {
        return range(1, number+1).filter(new F<Integer, Boolean>() {
            public Boolean f(final Integer i) {
                return number % i == 0;
            }
        });
    }

    public int sum(List<Integer> factors) {
        return factors.foldLeft(add, 0);
    }

    public boolean isPerfect(int number) {
        return sum(factorsOf(number)) - number == number;
    }

    public boolean isAbundant(int number) {
        return sum(factorsOf(number)) - number > number;
    }

    public boolean isDeficiend(int number) {
        return sum(factorsOf(number)) - number < number;
    }
}
```

```java
public int sum(List<Integer> factors) {
    return factors.foldLeft(add, 0);
}
```

```java
public int sum(List<Integer> factors) {
    return factors.foldLeft(fj.function.Integers.add, 0);
}
```



think about results,
not steps

```java
public List<Integer> factorsOf(final int number) {
    return range(1, number+1).filter(new F<Integer, Boolean>() {
        public Boolean f(final Integer i) {
            return number % i == 0;
        }
    });
}
```

12

1 2 3 4 5 6 7 8 9 10 11 12

```java
public boolean isFactor(int number, int potential_factor) {
    return number % potential_factor == 0;
}

public List<Integer> factorsOf(final int number) {
    return range(1, number+1).filter(new F<Integer, Boolean>() {
        public Boolean f(final Integer i) {
            return number % i == 0;
        }
    });
}

public int sum(List<Integer> factors) {
    return factors.foldLeft(fj.function.Integers.add, 0);
}
```

think about results,
not steps

Clojure

List comprehension

```
(defn factors [number]
  (set (for [n (range 1 (inc number))
        :when (is-factor? n number)] n)))
```

return the list as a set

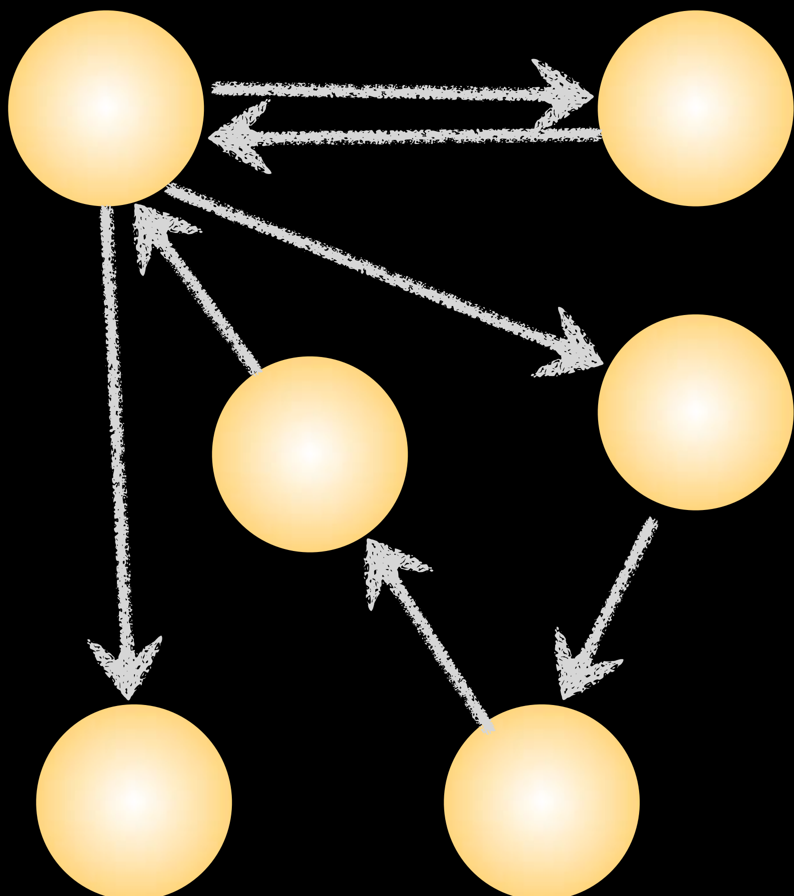
for each n in range from 1 to (number + 1)

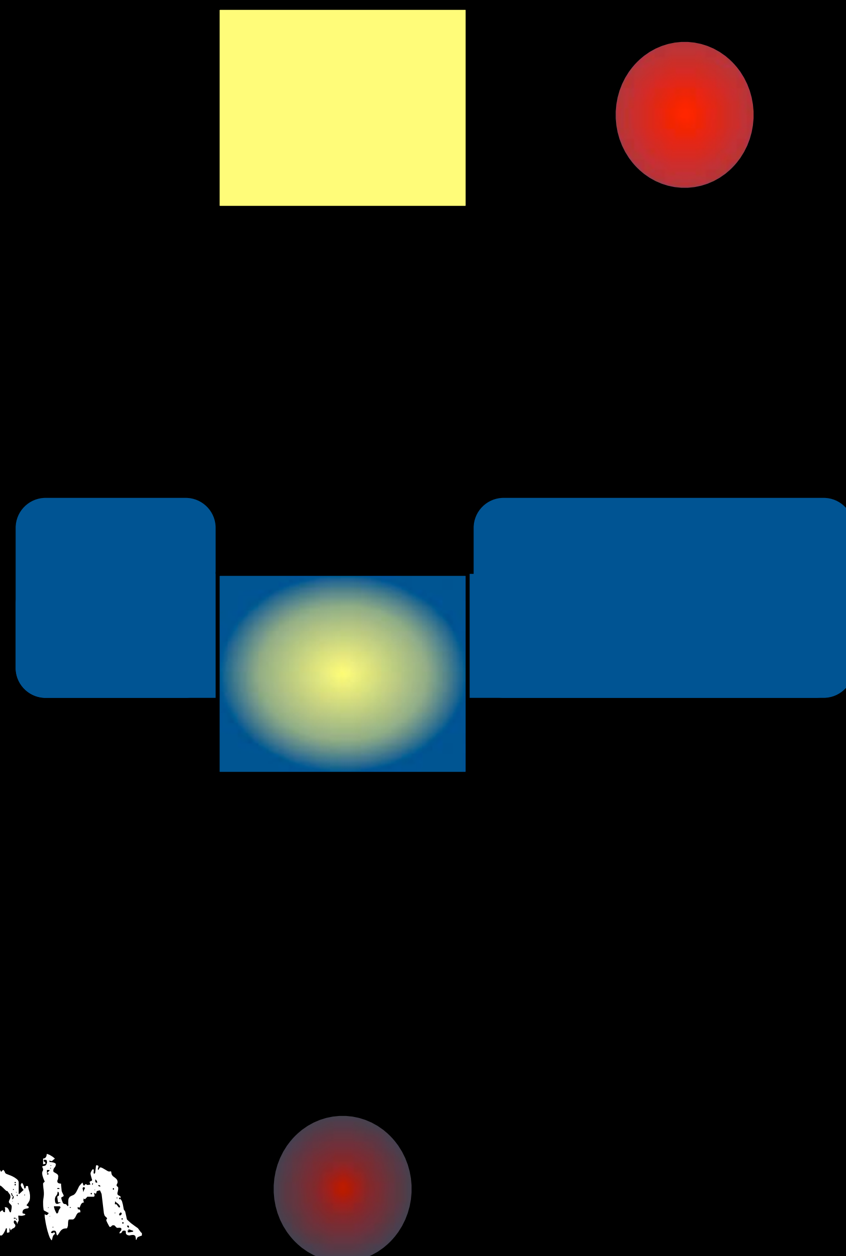
filter list by criteria my is-factor? function

return the numbers that match

```clojure
(defn is-factor? [factor number]
  (= 0 (rem number factor)))

(defn factors [number]
  (set (for [n (range 1 (inc number))
        :when (is-factor? n number)] n)))

(defn sum-factors [number]
    (reduce + (factors number)))

(defn perfect? [number]
  (= number (- (sum-factors number) number)))
```

Clojure





composition


academia
alert!

currying

given: $f\colon (X \times Y) \to Z$

then: $\mathrm{curry}(f) : X \to (Y \to Z)$

<u>currying</u> takes a function with a particular number of parameters and returns a function with some of the parameter values fixed, creating a new function

```
def product = { x, y ->
  return x * y
}
```

return a version that always multiplies by 4

```
def quadrate = product.curry(4)
```

==

```
def quadrate_ = { y ->
  return 4 * y
}
```

```
def product = { x, y ->
  return x * y
}

def quadrate = product.curry(4)
def octate = product.curry(8)

println "4x4: ${quadrate.call(4)}"
println "5x8: ${octate(5)}"
```

function reuse

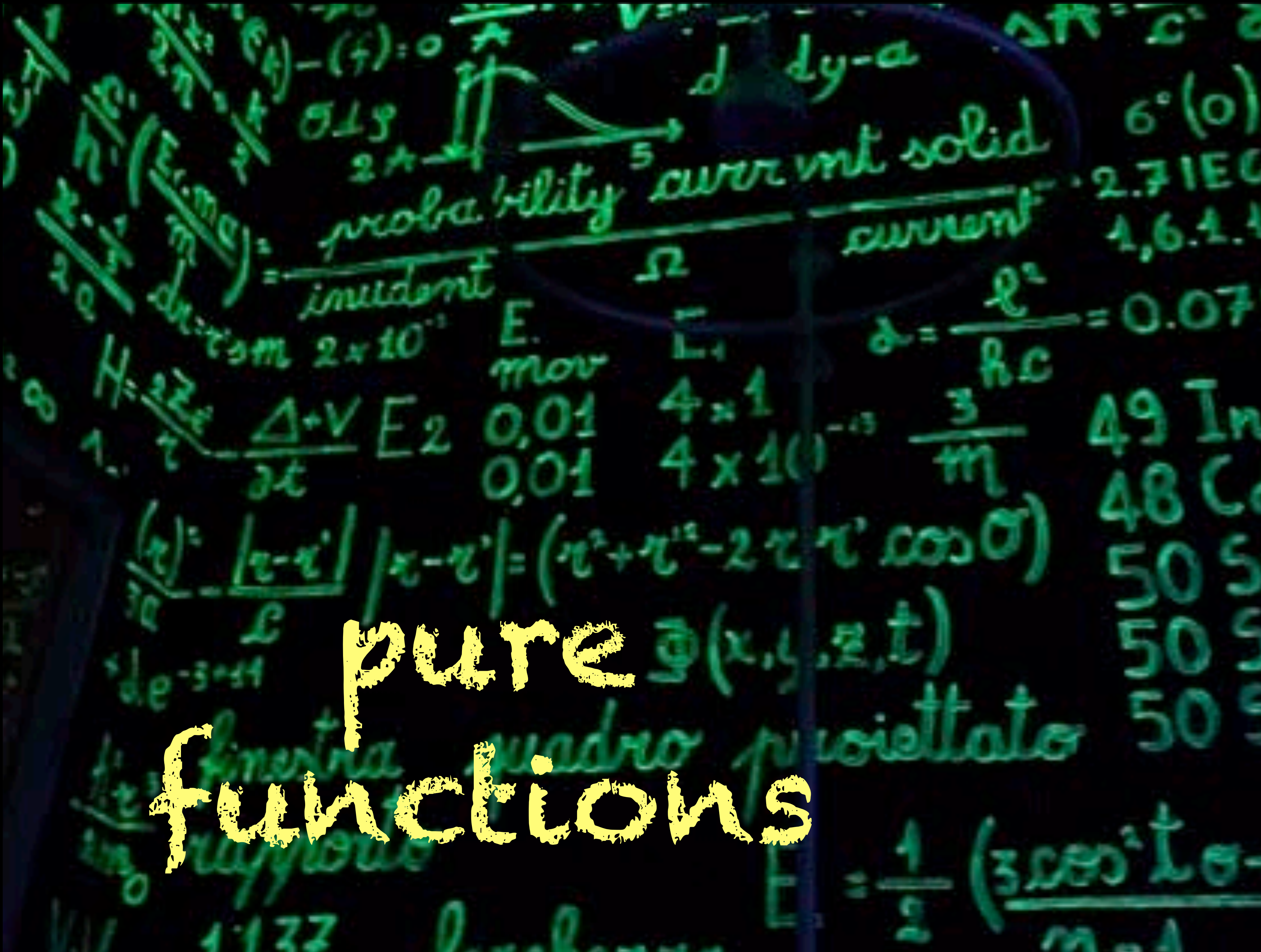
```
def adder = { x, y -> x + y}
def inc = adder.curry(1)
```

```
def composite = { f, g, x -> return f(g(x))}
def thirtyTwoer = composite.curry(quadrate, octate)
```

new, different tools

currying

```scala
object CurryTest extends Application {

  def filter(xs: List[Int], p: Int => Boolean): List[Int] =
    if (xs.isEmpty) xs
    else if (p(xs.head)) xs.head :: filter(xs.tail, p)
    else filter(xs.tail, p)

  def dividesBy(n: Int)(x: Int) = ((x % n) == 0)

  val nums = List(1, 2, 3, 4, 5, 6, 7, 8)
  println(filter(nums, dividesBy(2)))
  println(filter(nums, dividesBy(3)))
}
```



pure functions

pure functions

no memory or i/o side effects

purity

if the result isn't used, it can be removed

a particular invocation with a set of parameters returns a constant value

enables memoization

execution order can change

parallel execution

recursion

iterative filtering

```
def filter(list, criteria) {
  def new_list = []
  list.each { i ->
    if (criteria(i))
      new_list << i
  }
  return new_list
}

modBy2 = { n -> n % 2 == 0}

l = filter(1..20, modBy2)
```

recursive filtering

```scala
object CurryTest extends Application {

  def filter(xs: List[Int], p: Int => Boolean): List[Int] =
    if (xs.isEmpty) xs
    else if (p(xs.head)) xs.head :: filter(xs.tail, p)
    else filter(xs.tail, p)

  def dividesBy(n: Int)(x: Int) = ((x % n) == 0)

  val nums = List(1, 2, 3, 4, 5, 6, 7, 8)
  println(filter(nums, dividesBy(2)))
  println(filter(nums, dividesBy(3)))
}
```

think about results,
not steps

http://www.scala-lang.org/node/135

think about results, not steps

what about things you want to control?

performance?

new, different tools

imperative number classifier

```java
public class Classifier6 {
    private Set<Integer> _factors;
    private int _number;

    public Classifier6(int number) {…

    private boolean isFactor(int factor) {…

    public Set<Integer> getFactors() {…

    private void calculateFactors() {
        for (int i = 2; i < sqrt(_number) + 1; i++)
            if (isFactor(i))
                addFactor(i);
    }

    private void addFactor(int factor) {
        _factors.add(factor);
        _factors.add(_number / factor);
    }
}
```

optimized!

optimized factors

```
public List<Integer> factorsOfOptimzied(final int number) {
    List<Integer> factors = range(1, (int) round(sqrt(number)+1))
            .filter(new F<Integer, Boolean>() {
                public Boolean f(final Integer i) {
                    return number % i == 0;
                }
            });
    return factors.append(factors.map(new F<Integer, Integer>() {
        public Integer f(final Integer i) {
            return number / i;
        }
    }));
}
```

think about results,
not steps

post-imperative

Google challenged college grads to write code for 100 CPU computers...

...they failed

http://broadcast.oreilly.com/2008/11/warning-x-x-1-may-be-hazardous.html

ingrained imperativity

learn MapReduce

http://code.google.com/edu/submissions/mapreduce-minilecture/listing.html

sound familiar?

languages handle

garbage collection

concurrency

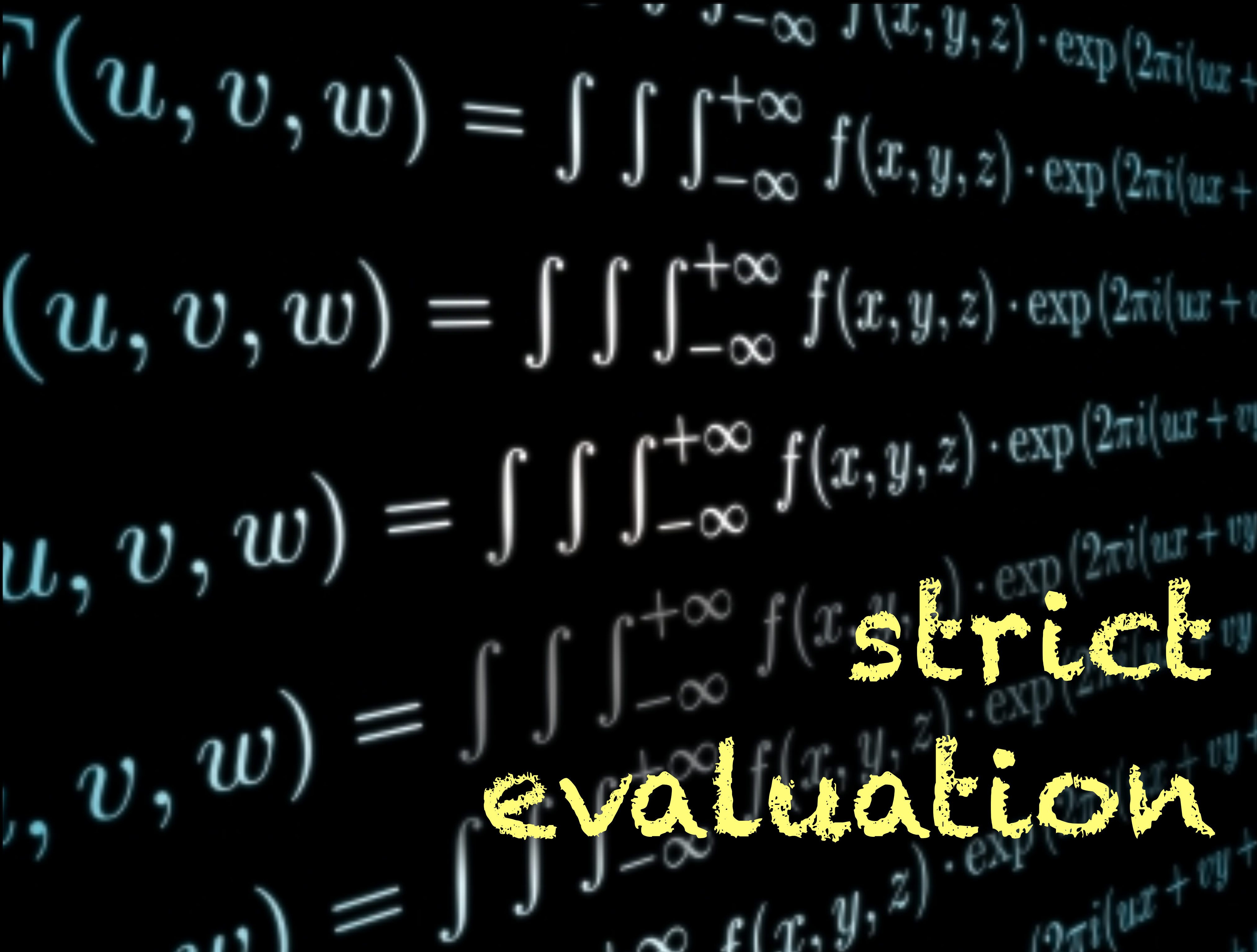
state

tests

iteration

. . .

time



strict evaluation


academia
alert!

strict evaluation

all elements pre-evaluated

divByZero

```
print length([2+1, 3*2, 1/0, 5-4])
```

=4

non-strict evaluation

elements evaluated as needed


Laziness

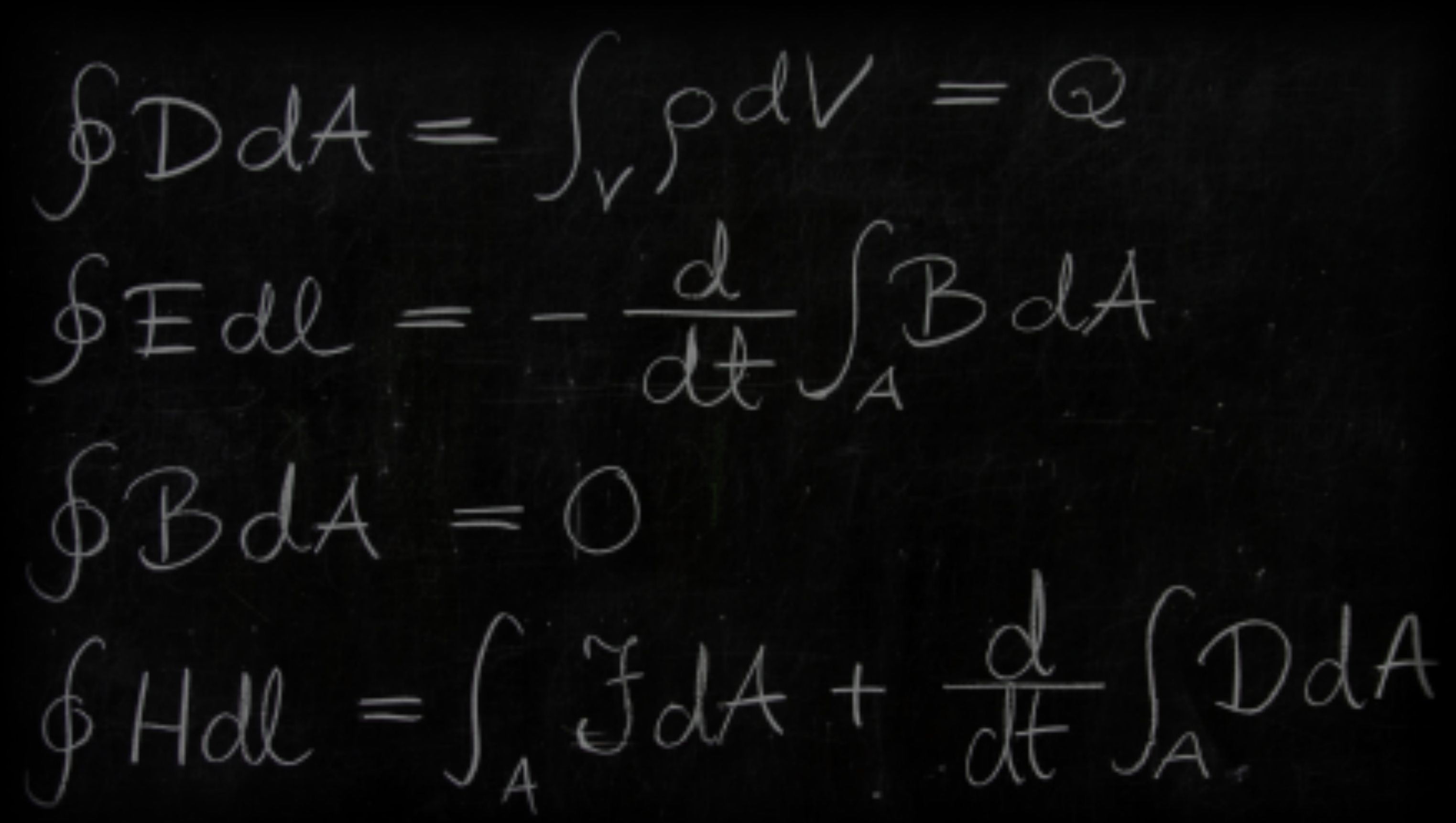
```clojure
(use '[clojure.contrib.lazy-seqs :only (primes)])

(def ordinals-and-primes
     (map vector (iterate inc 1) primes))

(take 5 (drop 1000 ordinals-and-primes))
```

```
([1001 7927] [1002 7933] [1003 7937] [1004 7949] [1005 7951])
```

Clojure

new, different tools

concurrency



functions:

depend only on their arguments

given the same arguments, return the same values

no effect on the world

no notion of time

most programs are processes

expect change over time

affect the world

wait for external events

produce different answers at different times what can we add to functional programming to deal with processes?

variables

assume 1 thread of control, 1 timeline

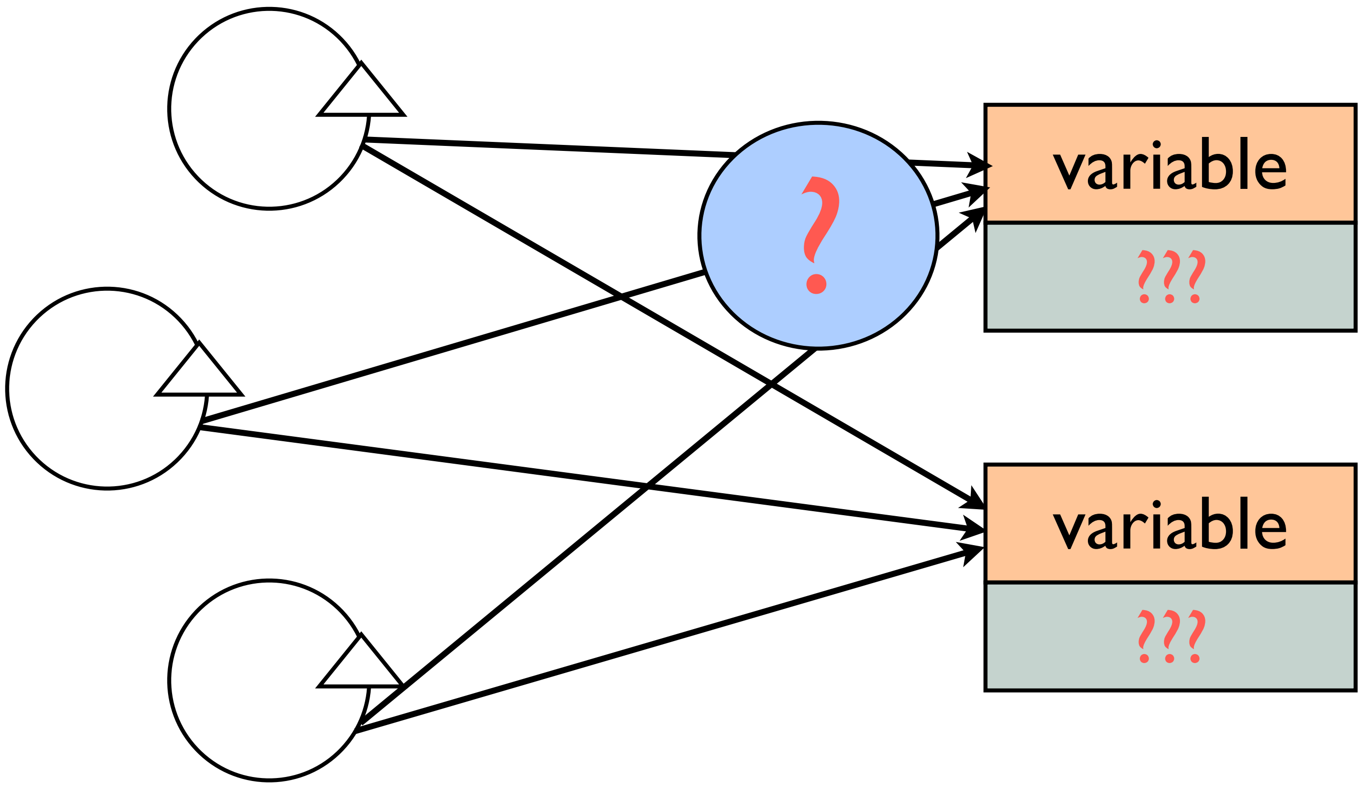
not atomic

non-composable

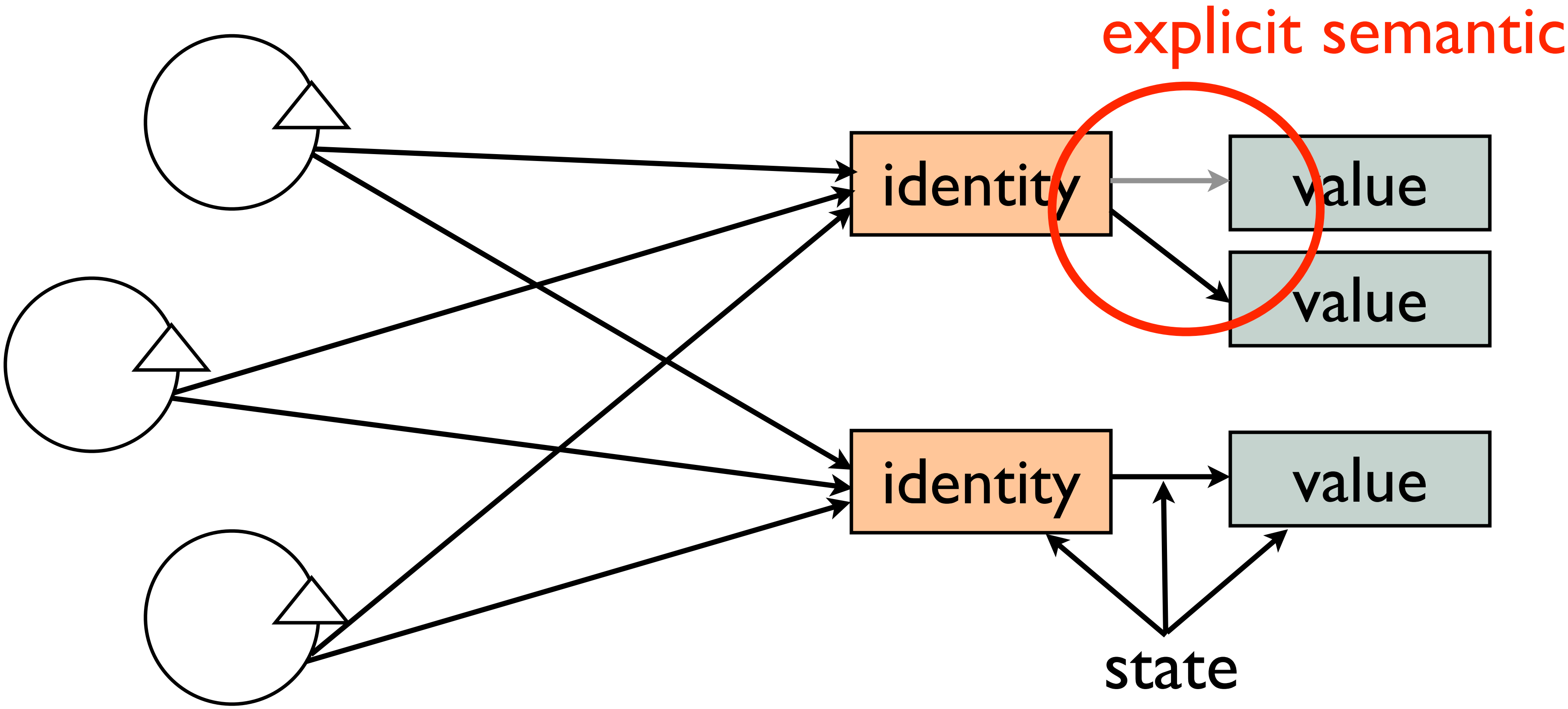
subtle visibility rules

with concurrency: **lock & pray**

life w/ variables



identity

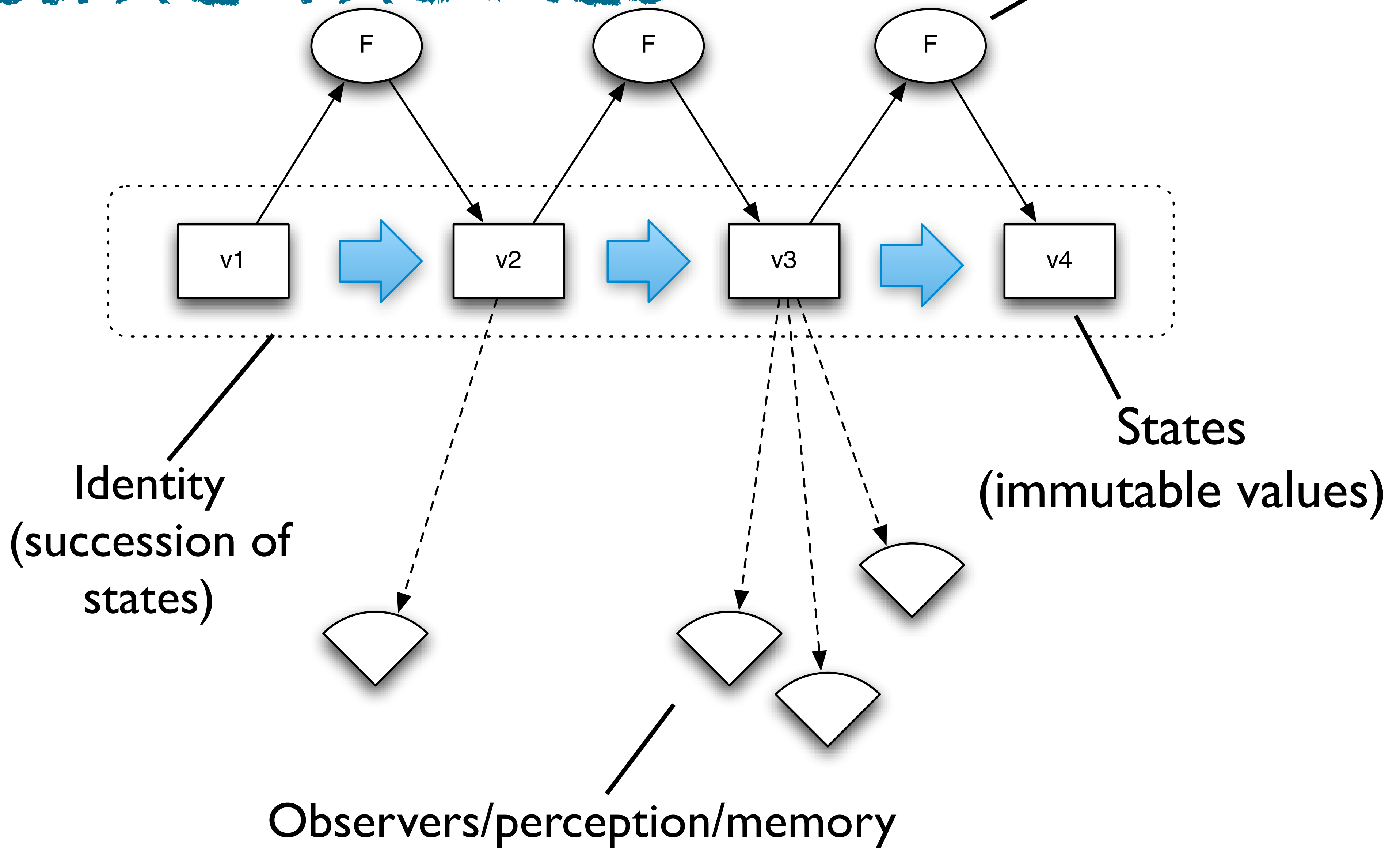

explicit semantic
identity
value
value
identity
value
state

identity, state, & time

term	meaning
value	immutable data in a persistent data structure
identity	series of causally related values over time
state	identity at a point in time
time	relative: before/ simultaneous/after ordering of causal values

Clojure

Clojure epochal time model

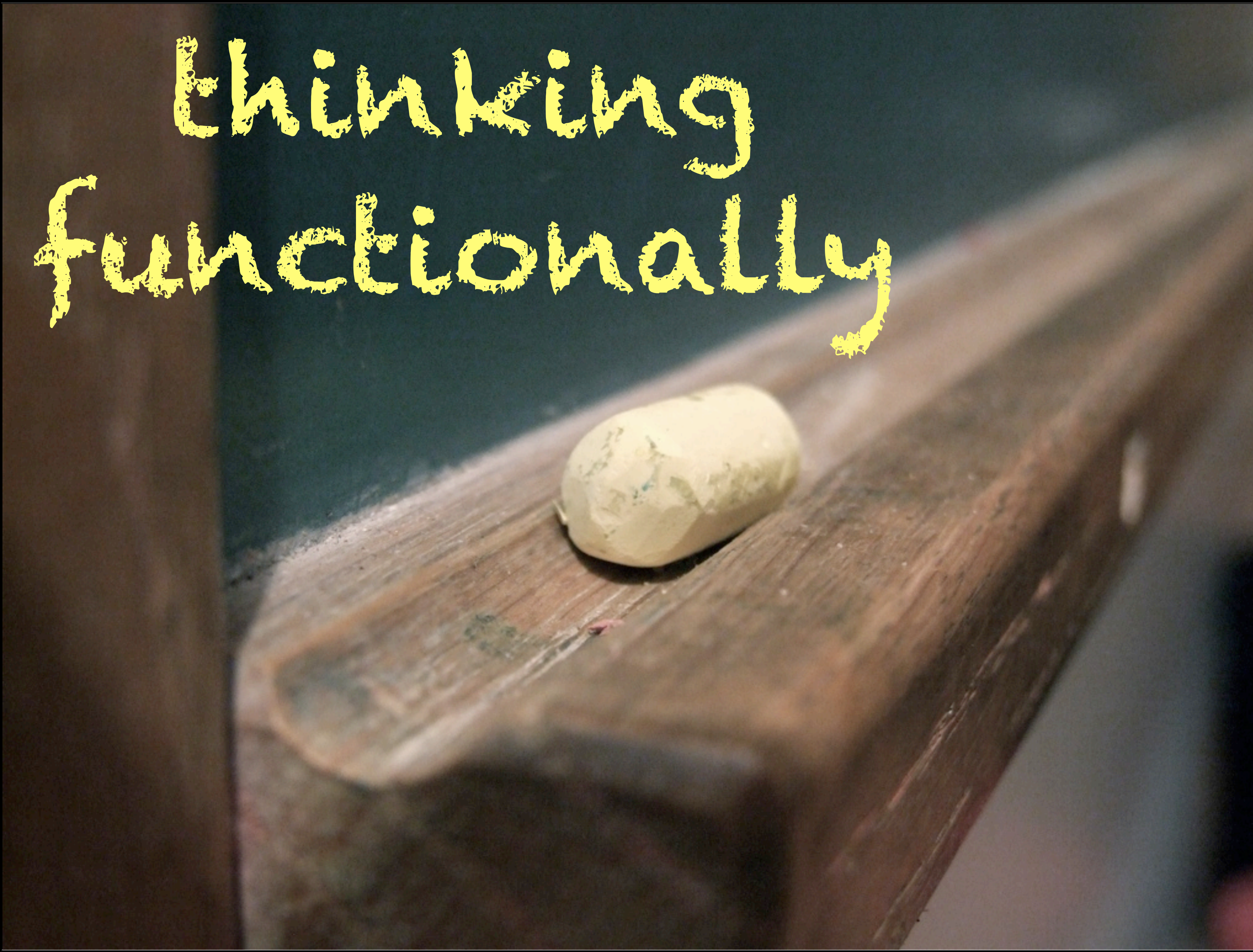


$$\delta_{ijt} = \frac{(v_{ijt} / \sum_{i=1}^{n} v_{ijt}) \times 100 - (r_{ijt} / \sum_{i=1}^{n} r_{ijt}) \times 100}{\sigma(\delta_{ij})}$$

actors

```scala
def isPerfect(candidate: Int) =
{
  val RANGE = 1000000
  val numberOfPartitions = (candidate.toDouble / RANGE).ceil.toInt

  val caller = self

  for (i <- 0 until numberOfPartitions) {
    val lower = i * RANGE + 1;
    val upper = candidate min (i + 1) * RANGE

    actor {
      var partialSum = 0
      for(j <- lower to upper)
        if (candidate % j == 0) partialSum += j

      caller ! partialSum
    }
  }

  var responseExpected = numberOfPartitions
  var sum = 0
  while(responseExpected > 0) {
    receive {
      case partialSum : Int =>
        responseExpected -= 1
        sum += partialSum
    }
  }

  sum == 2 * candidate
}
```

new, different tools


thinking
functionally

immutability over state transitions

http://www.ibm.com/developerworks/java/library/j-jtp02183/index.html

results
over
steps

composition

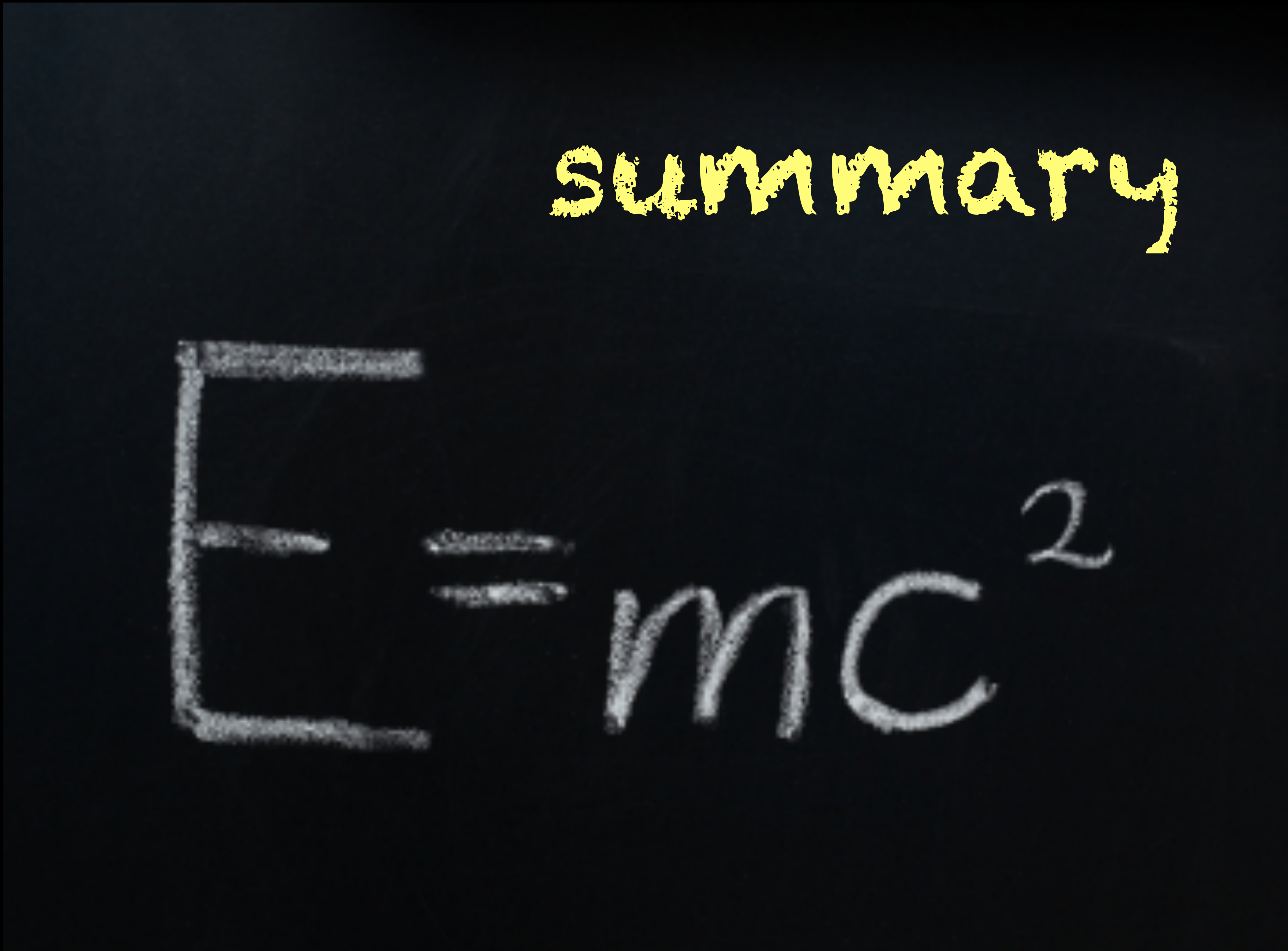
over

structure

declarative over imperative

paradigm over tool

summary



functional thinking

new ways of thinking about design

new tools for extension, reuse, etc.

immediately beneficial beginning steps

following the general trend in language design

enables entirely new capabilities

?'s

please fill out the session evaluations

NEAL FORD software architect / meme wrangler

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