Fun for Freshman Kids

Felleisen, Findler, Flatt, Krishnamurthi
PLT

interview with famous FP person in trade magazine, feb. '09

Question: Should functional programming be ... the first thing [programmers] learn?

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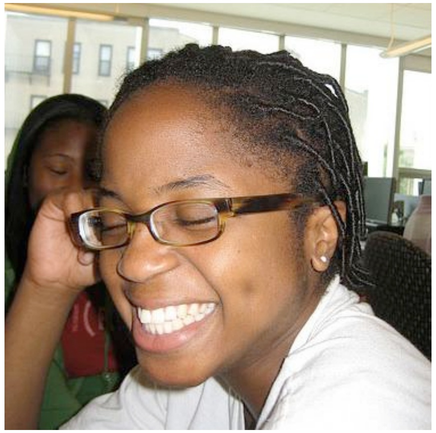
Question: Should functional programming be ... the first thing [programmers] learn?

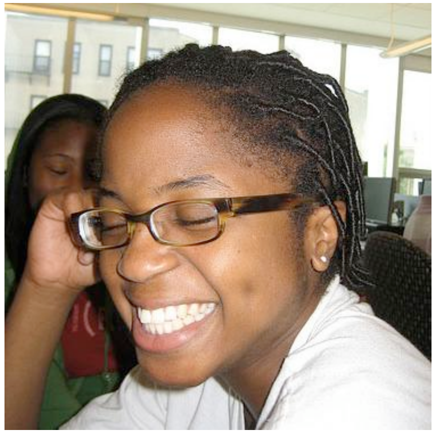
Answer: I don't actually have a very strong opinion on that. I think there are a lot of related factors, such as what the students will put up with! I think student motivation is very important, so ***teaching students a language they have heard of as their first language*** has a powerful motivational factor.

game by inner city middle school student, feb. '09



Christine's programming language is *pure middle school mathematics* (in Scheme syntax of course):

variable expressions, functions, conditional functions, function composition.



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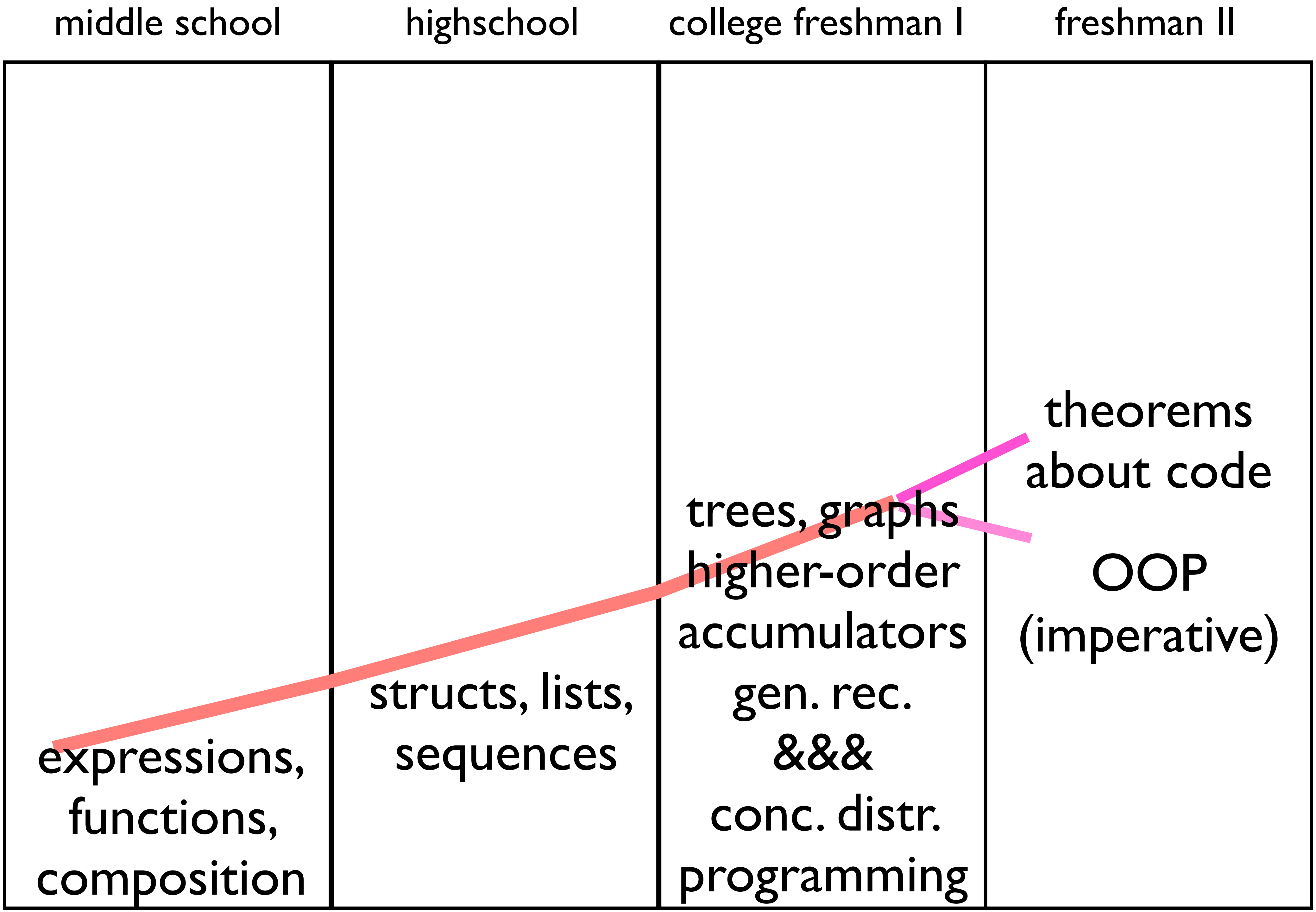
Trick: Christine doesn't know that it's mathematics.


middle school
highschool
college freshman I
freshman II
expressions,
functions,
composition
structs, lists,
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trees, graphs
higher-order
accumulators
gen. rec.
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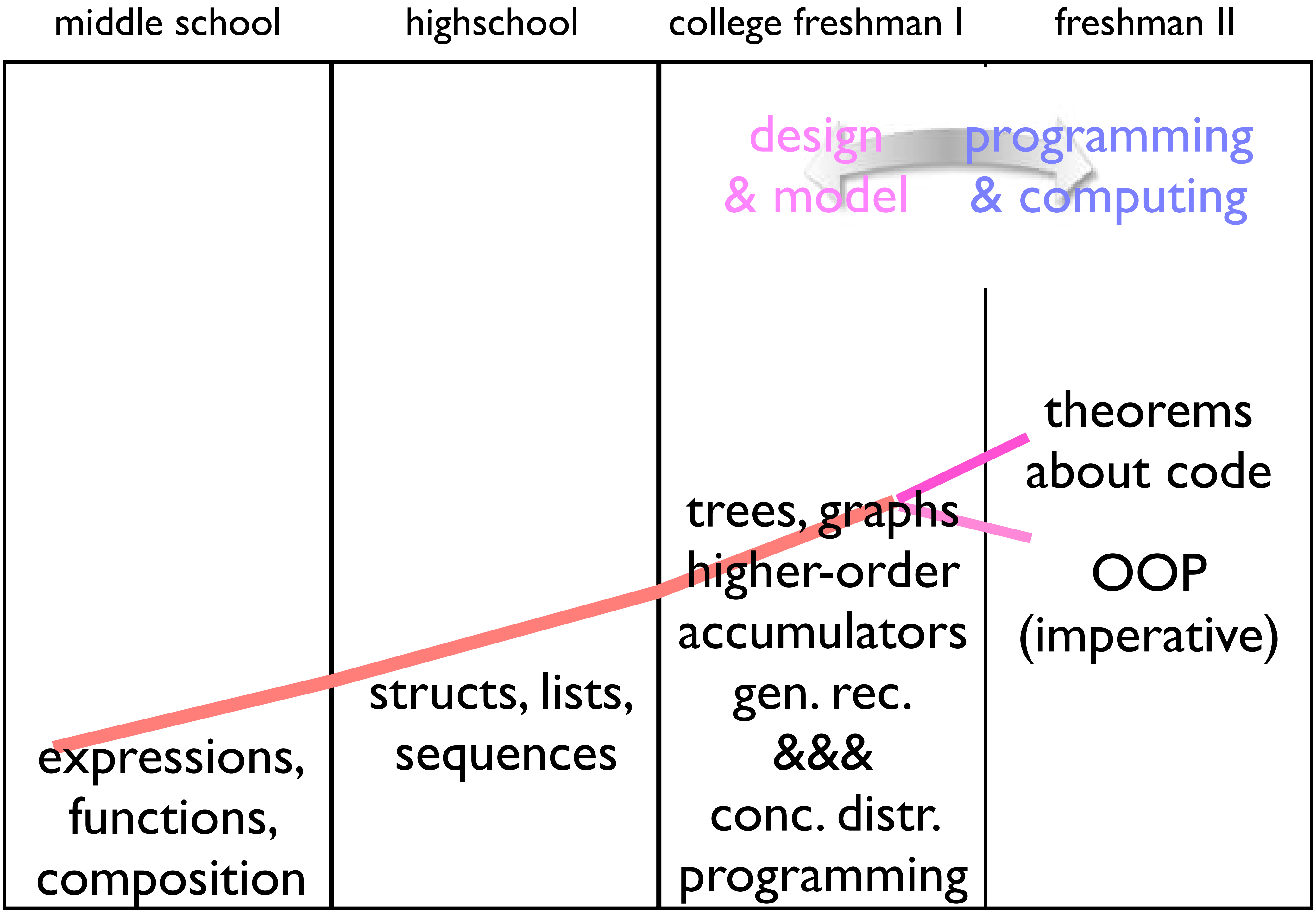
about code
OOP
(imperative)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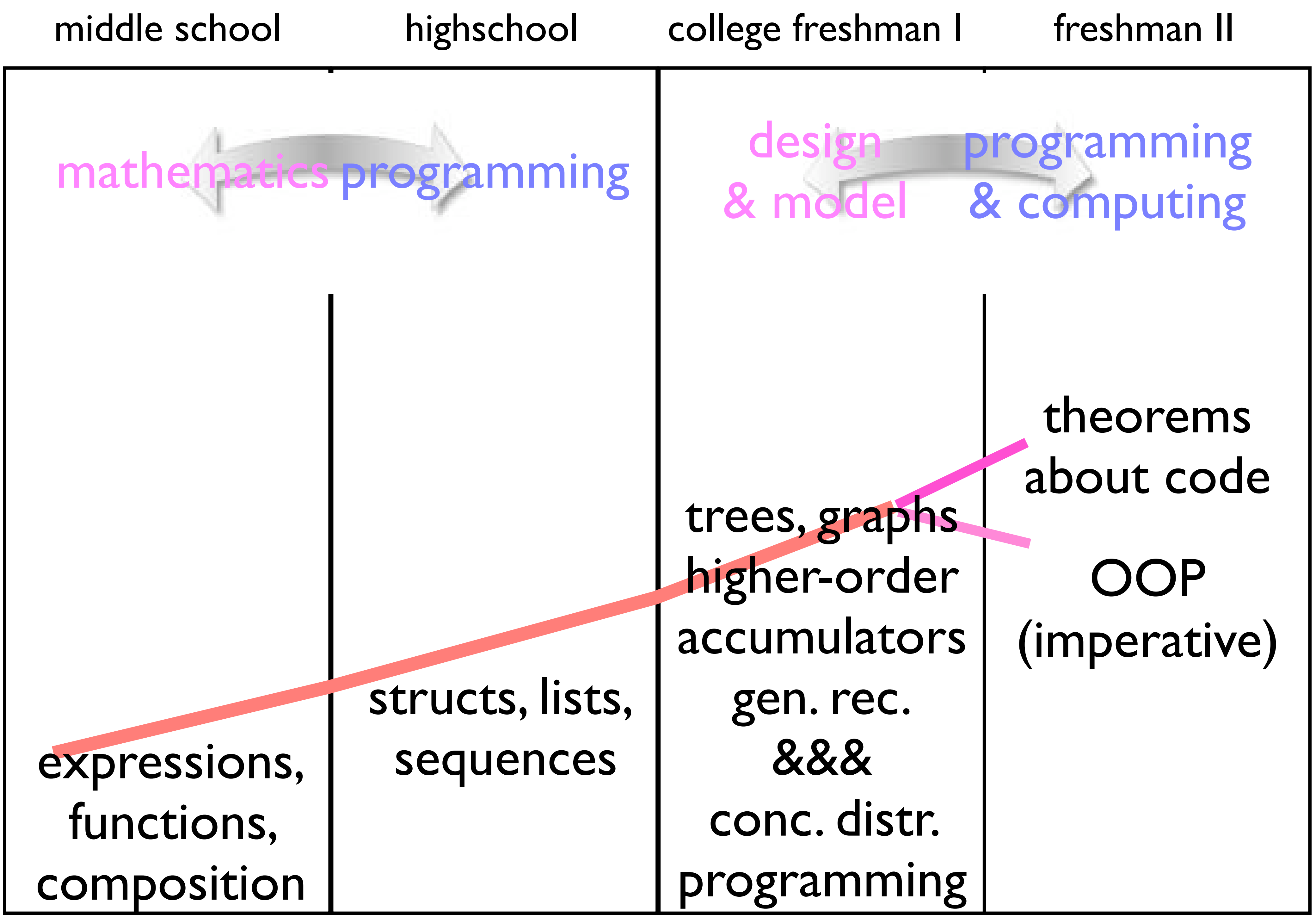
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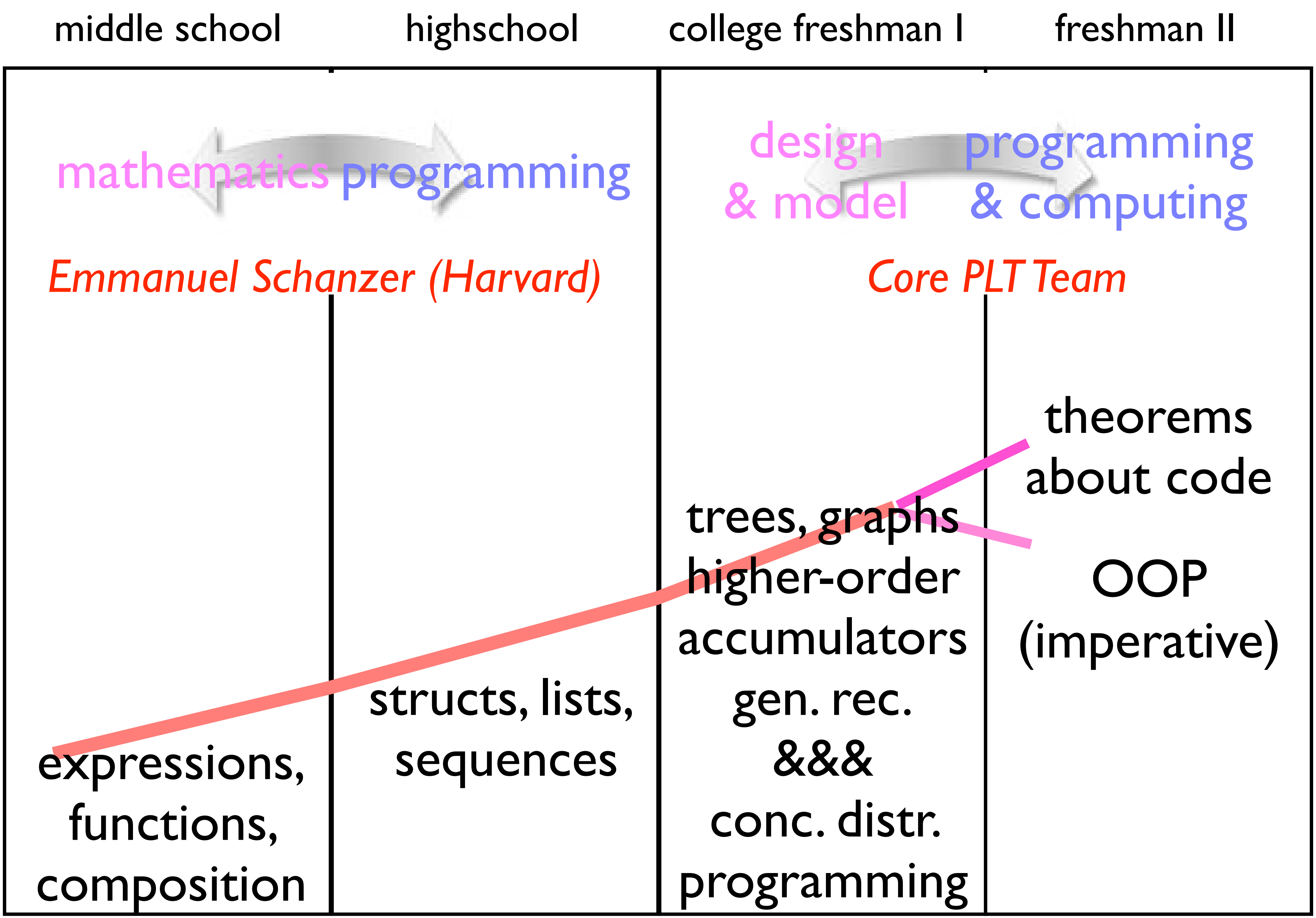

middle school
highschool
college freshman I
freshman II
mathematics
programming
design
& model
programming
& computing
Emmanuel Schanzer (Harvard)
Core PLT Team
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How did we get there?

A Functional I/O System

Felleisen, Findler, Flatt, Krishnamurthi
PLT

Diagnosis: Students wish to write programs like those that they use, with interactive GUIs.

Apparently functional programming languages must abandon "purity" via monads and/or other advanced type machinery to compete with imperative languages.

Manuel Chakravarty and Gabriele Keller,
J. Functional Programming, volume **14**(1)

The Abstract Idea:

Turn mathematical functions into event handlers.
The underlying OS performs all imperative actions.

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The underlying OS performs all imperative actions.

The Concrete Idea:

Think of the world as a collection of states,
clock ticks, mouse events, ... trigger transitions.

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Turn mathematical functions into event handlers.
The underlying OS performs all imperative actions.

The Concrete Idea:

Think of the world as a collection of states,
clock ticks, mouse events, ... trigger transitions.

The Best Part:

No threading required. No monad. No arrows.
No nothing.

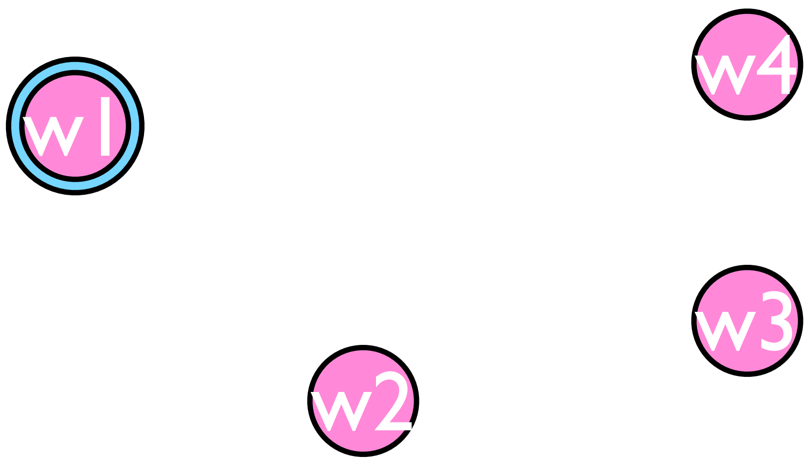
The OS

import

type World

export

```
val big-bang : World
        * (World -> World)
        * (World KeyEvt -> World)
        * (World Nat Nat MouseEvt -> World)
        -> World
```



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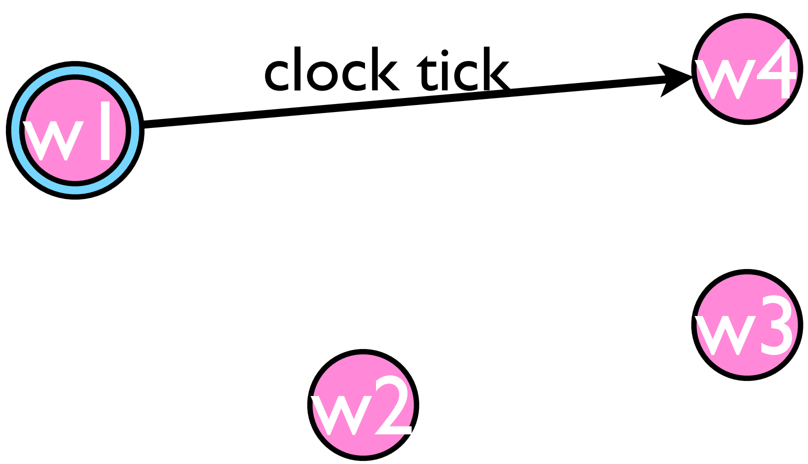

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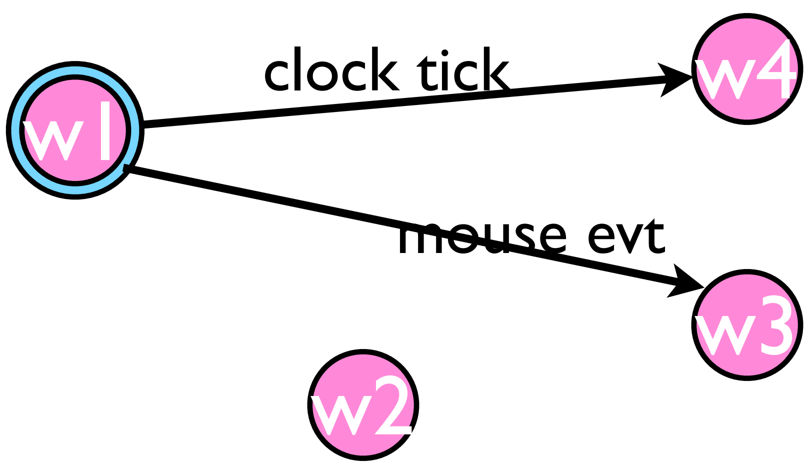

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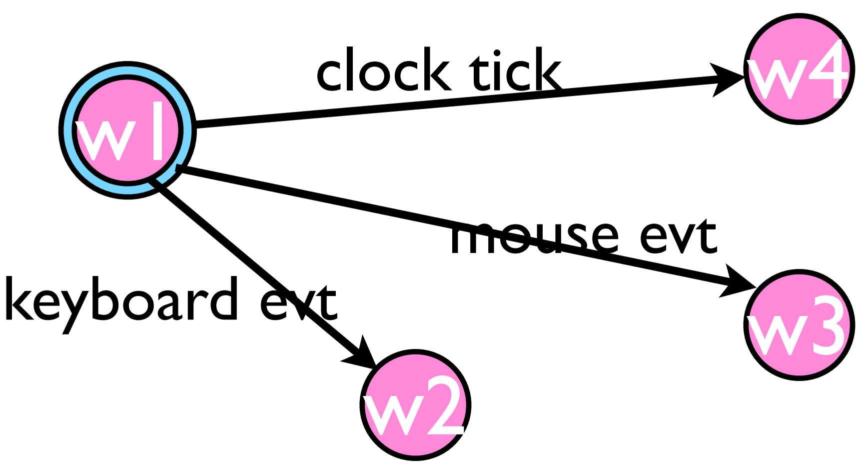

import

type World

export

val big-bang : World

* (World -> World)
* (World KeyEvt -> World)
* (World Nat Nat MouseEvt -> World)
-> World

the initial world

```
import
  type World

export
  val big-bang : World
             * (World -> World)
             * (World KeyEvt -> World)
             * (World Nat Nat MouseEvt -> World)
             -> World
```

call for every clock tick

import

```
type World
```

export

```
val big-bang : World
             * (World -> World)
             * (World KeyEvt -> World)
             * (World Nat Nat MouseEvt -> World)
             -> World

type KeyEvt <= String
val key=? : KeyEvt KeyEvt -> Boolean
```

call for every keyboard event

```
import
  type World

export
  val big-bang : World
               * (World -> World)
               * (World KeyEvt -> World)
               * (World Nat Nat MouseEvt -> World)
               -> World

  type KeyEvt <= String
  val key=? : KeyEvt KeyEvt -> Boolean

  type MouseEvt = "button-down" | ...
  val mouse=? : MouseEvt MouseEvt -> Boolean
```

call for *many* mouse events

import

```
type World
```

export

```
val big-bang : World
            * (World -> W
            * (World K
            * (World Na                    > World)
            -> World
```

the final world

```
type KeyEvt <= String
val key=? : KeyEvt KeyEvt -> Boolean

type MouseEvt <= String
val Mouse=? : MouseEvt MouseEvt -> Boolean
```

```
import
  type World

export
  val big-bang : World
            * (World -> World)
            * (World KeyEvt -> Wo
            * (World Nat Nat Mou
            * (World -> Boolean)
            -> World

  type KeyEvt <= String
  val key=? : KeyEvt KeyEvt -> Boolean

  type MouseEvt <= String
  val Mouse=? : MouseEvt MouseEvt -> Boolean
```

should this be the *last* world?

import

```
type World
```

export

```
val big-bang : World
          * (World -> World)
          * (World KeyEvt -> World)
          * (World Nat Nat Mo
          * (World -> Boolean)
          * (World -> Image)
          -> World

type KeyEvt <= String
val key=? : KeyEvt KeyEvt -> Boolean

type MouseEvt <= String
val Mouse=? : MouseEvt MouseEvt -> Boolean
```

render the world

Universe

import

type World

export

```
val big-bang : World
             * (World -> World)
             * (World KeyEvt -> World)
             * (World MouseEvt -> World)
             * (World -> Boolean)
             * (World -> Image)
             -> World

type KeyEvt <= String
val key=? : KeyEvt KeyEvt -> Boolean

type MouseEvt <= String
val Mouse=? : MouseEvt MouseEvt -> ...
```

Universe

```
import
  type World

export
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               * (World -> World)
               * (World KeyEvt -> World)
               * (World MouseEvt -> World)
               * (World -> Boolean)
               * (World -> Image)
               -> World

  type KeyEvt <= String
  val key=? : KeyEvt KeyEvt -> Boolean

  type MouseEvt <= String
  val Mouse=? : MouseEvt MouseEvt -> ...
```

Student Program

export

type World = ...

import

big-bang

local

event handlers for

clock ticks

keyboard events

mouse events

renderer for translating states of the world into images

a stop? predicate

Universe

```
import
  type World

export
  val big-bang : World
              * (World -> World)
              * (World KeyEvt -> World)
              * (World MouseEvt -> World)
              * (World -> Boolean)
              * (World -> Image)
              -> World

  type KeyEvt <= String
  val key=? : KeyEvt KeyEvt -> Boolean

  type MouseEvt <= String
  val Mouse=? : MouseEvt MouseEvt -> ...
```

(Flatt et al: Units)

Student Program

export

type World = ...

import

big-bang

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event handlers for

clock ticks

keyboard events

mouse events

renderer for translating states of the world into images

a stop? predicate

That’s for you.

Reality: In PLT, *big-bang* is just a “little” language (aka macro) for describing worlds.

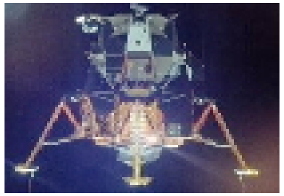
Example

```
;; World = NaturalNumber
;; interpretation: the distance of the LANDER from top

;; World -> World
(define (run y0)
  (big-bang y0 (on-draw to-image) (on-tick drop)))

;; World -> World
(define (drop y) (+ y 3))

;; World -> Image
(define (to-image y)
```



```
   (place-image [image] 400 y MOON))

(define MOON ...)
```

Example

```
;; World = NaturalNumber (0, 1, 2, ...)
;; interpretation: the distance of the LANDER from top

;; World -> World
(define (run y0)
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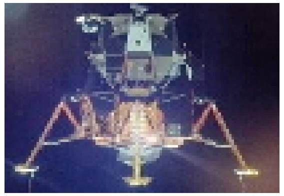

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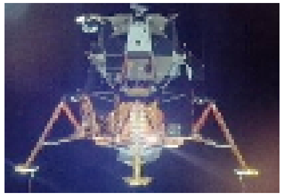

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   (place-image
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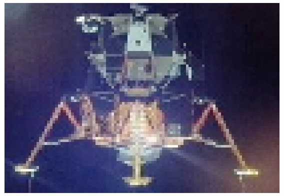

```
    400 y MOON))

(define MOON ...)
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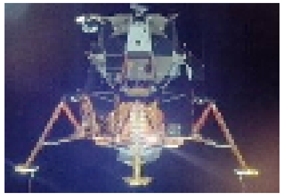

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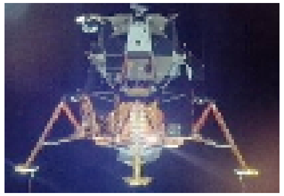

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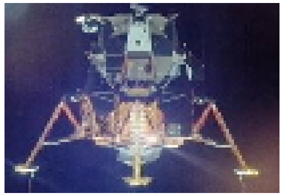

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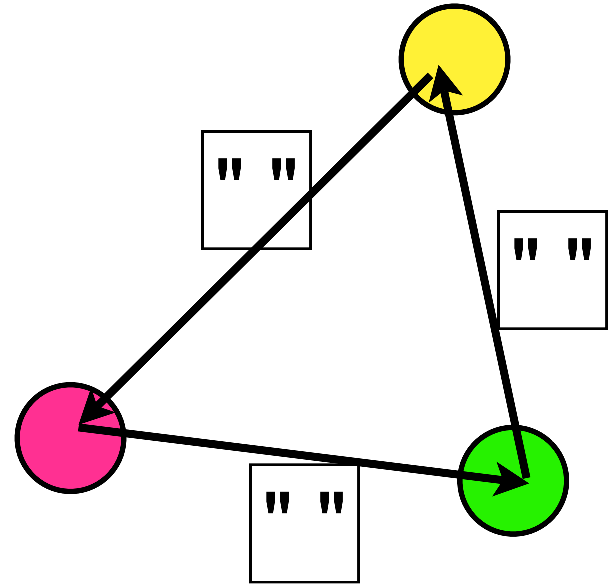
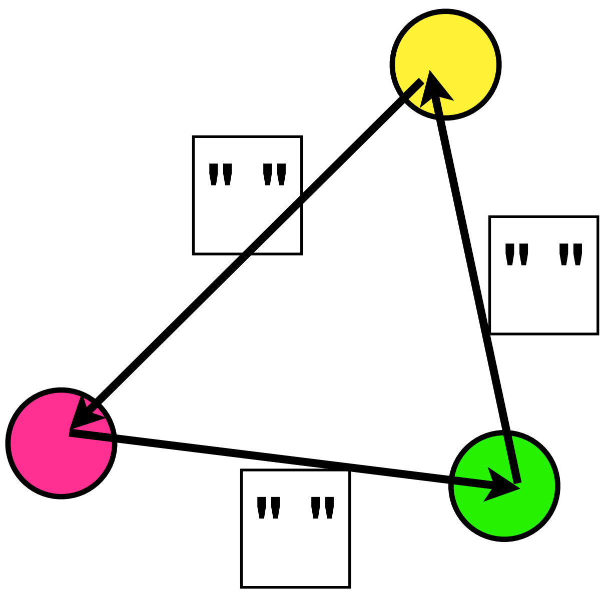


```
;;World is one of:
;; -- "red"
;; -- "green"
;; -- "yellow"
;; interpretation: the current state of the traffic light

;;World KeyEvt -> World
(define (world-switch s ke)
  (cond
    [(key=? ke " ") (light-switch s)]
    [else s]))

;;World -> World
(define (light-switch s)
  (cond
    [(string=? "red" s) "green"]
    [(string=? "green" s) "yellow"]
    [(string=? "yellow" s) "red"]))

;;World -> Image
(define (world-render s)
  (cond
    [(string=? "red" s) (place-image RED X Y RED LIGHT)]
    [(string=? "green" s) (place-image GREEN X Y GREEN LIGHT)]
    [(string=? "yellow" s) (place-image YELLOW X Y YELLOW LIGHT)]))

;;World -> World
(define (world-run s0)
  (big-bang s0
    (on-draw world-render)
    (on-key  world-switch)))

;; geometric constants
(define RADIUS 20)
...
```



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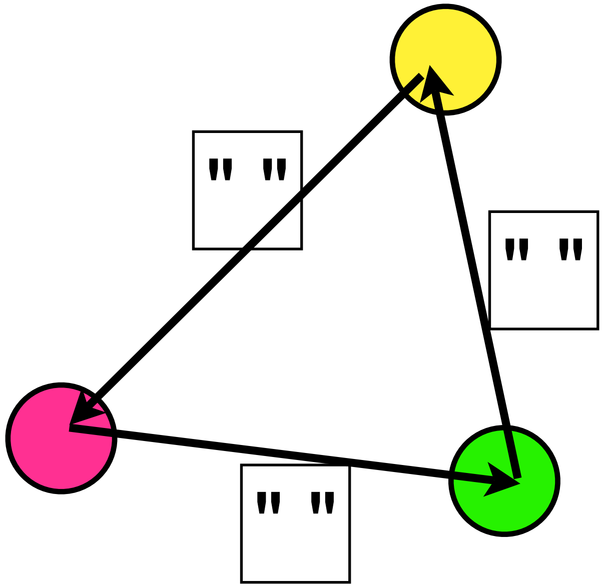
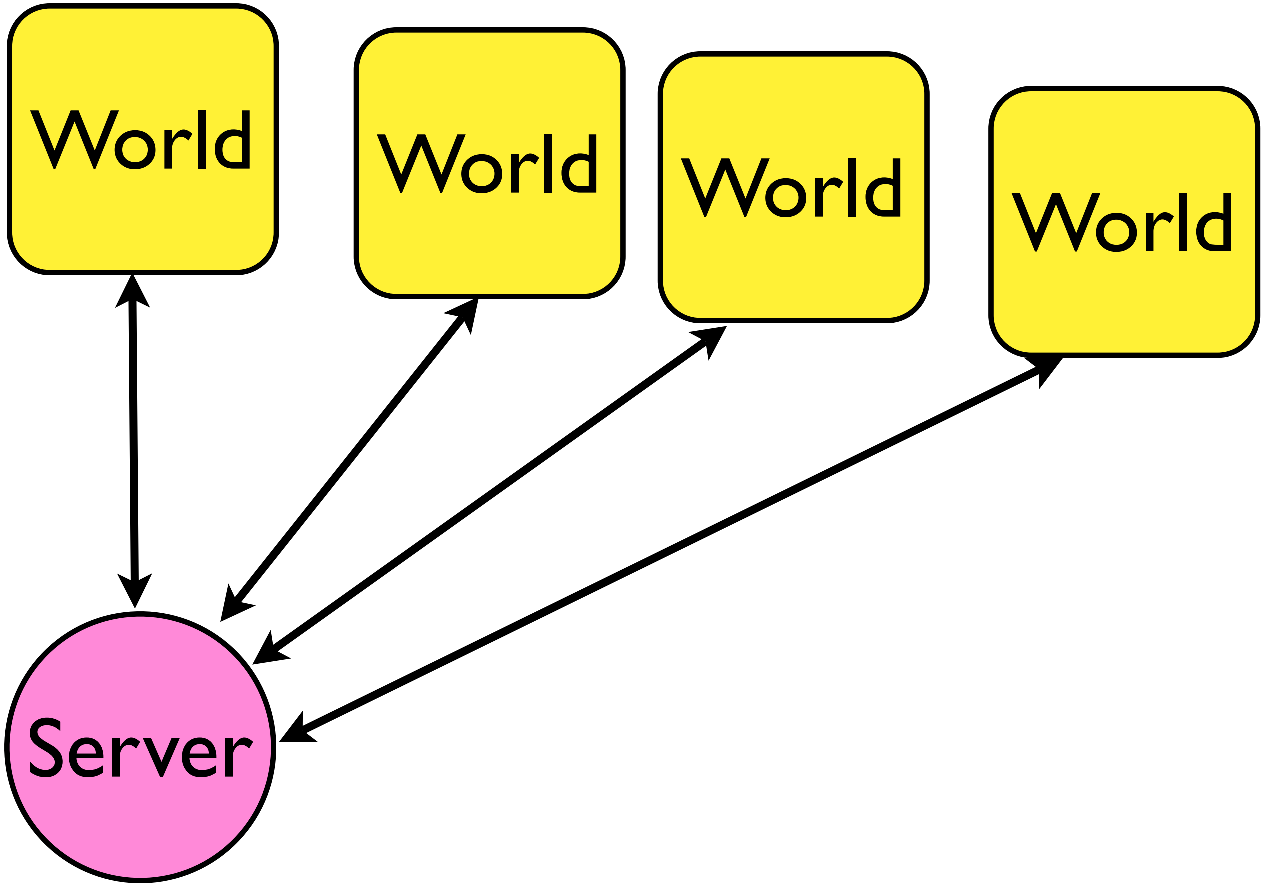
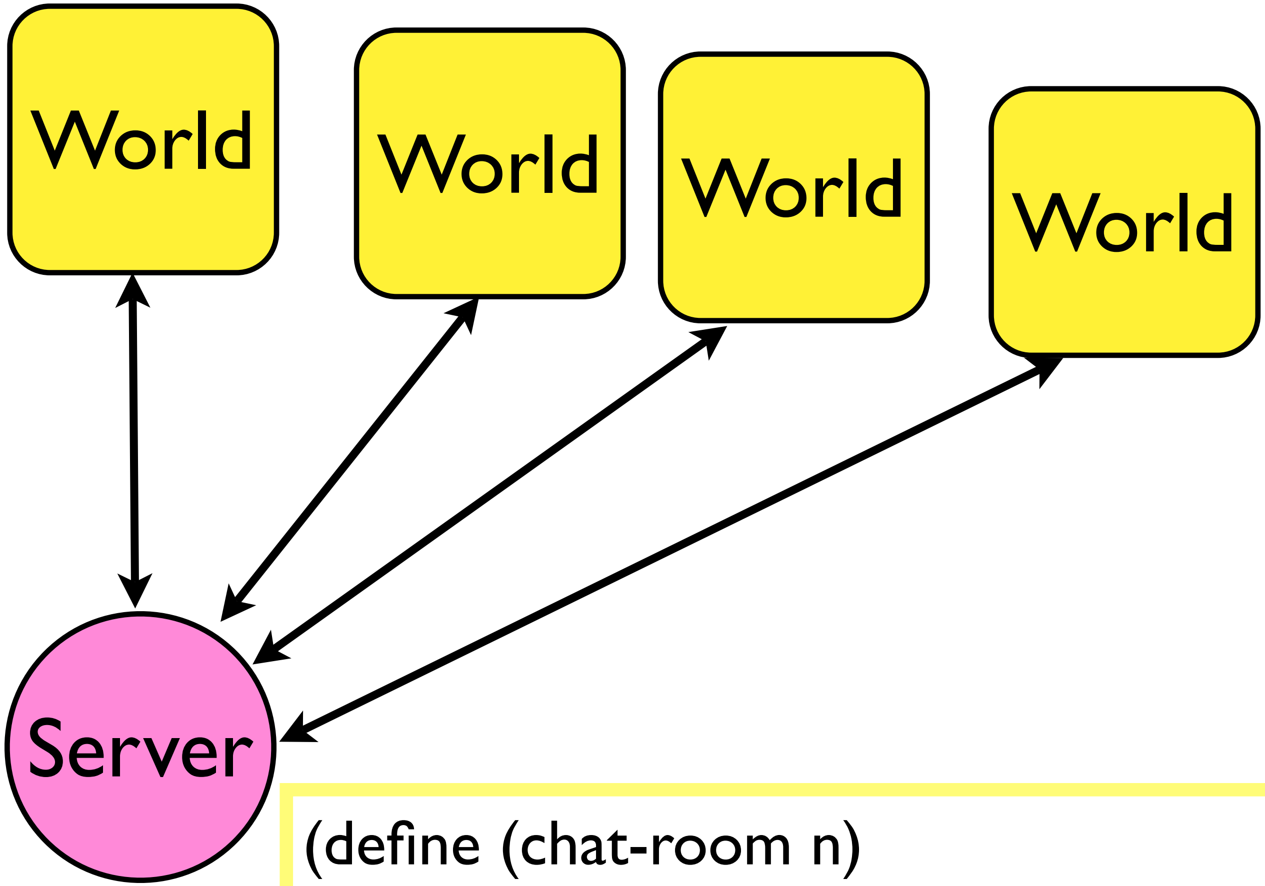


The World is Not Enough

Universe Programs for Connecting Distributed Worlds

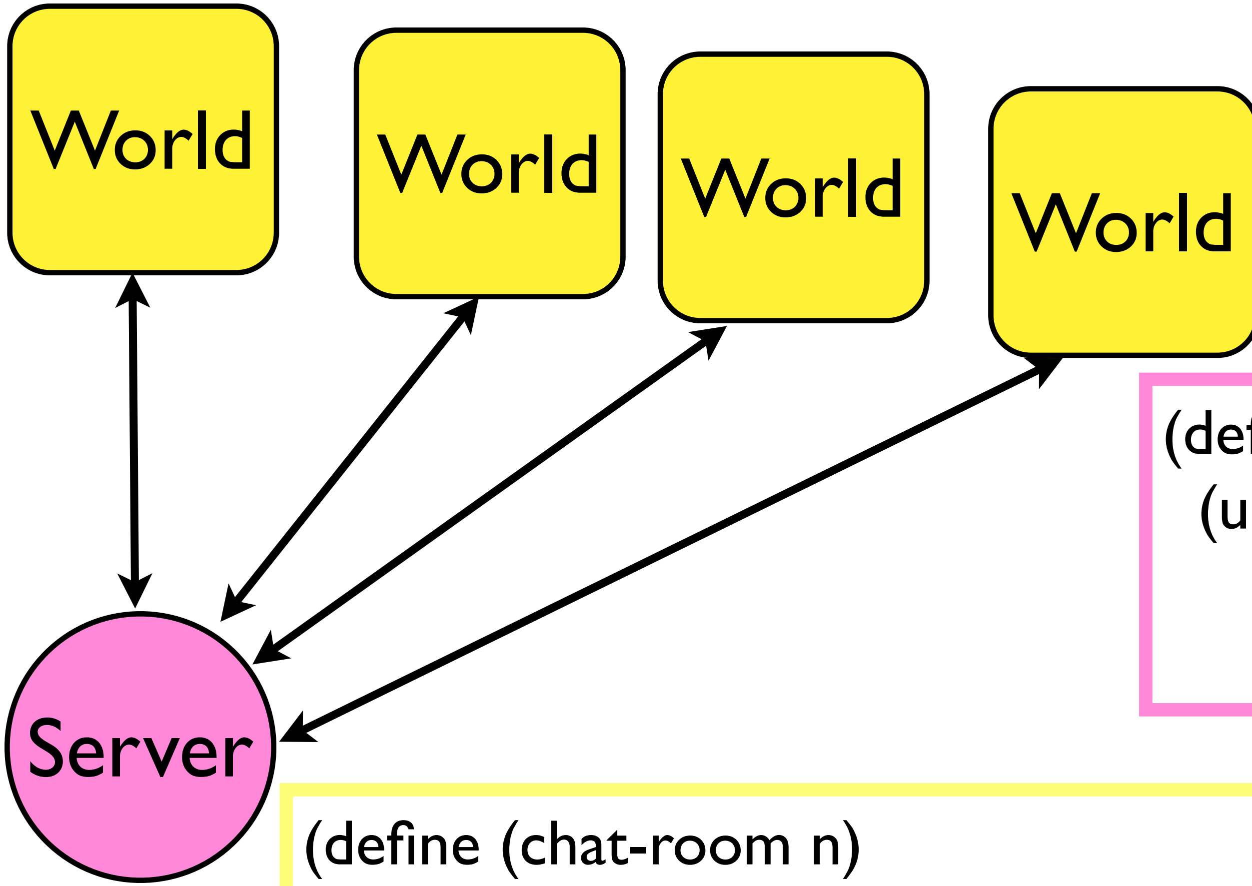


Universe Programs for Connecting Distributed Worlds




```
(define (chat-room n)
  (big-bang world0
          (name n)
          (on-key react) ;; World KeyEvt -> World | World * Message
          (on-draw render)
          (on-receive receive) ;; World * Message -> World * Message
          (register "america.ccs.neu.edu")))
```

Universe Programs for Connecting Distributed Worlds




```
(define (run _)
  (universe '()
            (on-new new-chatter)
            (on-msg forward)))
```

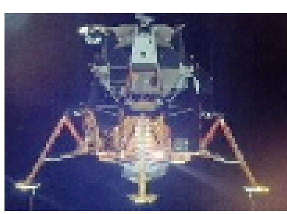
```
(define (chat-room n)
  (big-bang world0
            (name n)
            (on-key react) ;; World KeyEvt -> World | World * Message
            (on-draw render)
            (on-receive receive) ;; World * Message -> World * Message
            (register “america.ccs.neu.edu”)))
```

- the server can “pass through” packages (chat)
- the server can play referee (distributed games)
- the server can fake peer-to-peer (“Napster”)
- ... and it is all **functional**
- examples: binary games, distributed games, chat rooms, maze explorations;

Squint once and you get theorems ...

theorem proving for freshmen

```
;;World = NaturalNumber
;; interp.: the distance of the LANDER from top

;;World -> World
(defun run (y0)
  (big-bang y0 (on-draw to-image) (on-tick drop)
            (stop-when? too-low-on-screen)))

;;World -> World
(defun drop (y) (+ y 1))

;;World -> Image
(defun to-image (y)
```



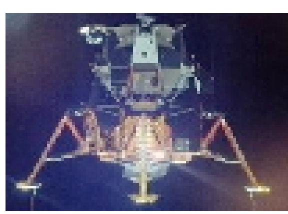
```
   (place-image [image] 400 y MOON))

(defthm lander-within-picture ...)
```

theorem proving for freshmen

;;World = NaturalNumber
;; interp.: the distance of the LANDER from top

;;World -> World
(**defun** run (y0)
  (**big-bang** y0 (on-draw to-image) (on-tick drop)
                (stop-when? too-low-on-screen)))

;;World -> World
(**defun** drop (y) (+ y 1))

;;World -> Image
(**defun** to-image (y)
  (place-image  400 y MOON))

(**defthm** lander-within-picture ...)

ACL2 via Dracula

Carl Eastlund (NEU)
& Rex Page (OK U)

Squint twice and you get objects ...

Functional Programming

```
(define-struct ufo (x y dx dy))
;; UFO = (make-ufo Nat Nat Integer Integer)
;; interp. the UFO's current location and velocity

;; UFO -> UFO
;; move this UFO for one tick
(define (ufo-move/tick u)
  (make-ufo (+ (ufo-x u) (ufo-dx u)) (ufo-y u) (ufo-dx u) (ufo-dy u)))

;; UFO Image -> Image
;; add this UFO to the given scene
(define (ufo-render u s)
   (place-image UFO (ufo-x u) (ufo-y u) s))


...
```

Applicative Objects

```
(define ufo%
  (class object%
   (init-field x y dx dy))
   ;; UFO = (new ufo% Nat Nat Integer Integer)
   ;; interp. the UFO's current location and velocity

   ;;  -> UFO
   ;; move this UFO for one tick
   (define/public (move/tick)
       (new ufo% (+ x dx) y dx dy))

   ;; UFO Image -> Image
   ;; add this UFO to the given scene
   (define/public (render s)
      (place-image UFO x y s))
  ... ))
```

Imperative Objects

```
(define ufo%
 (class object%
  (init-field x y dx dy))
  ;; UFO = (make-ufo Nat Nat Integer Integer)
  ;; interp. the UFO's current location and velocity

  ;;  -> VOID
  ;; move this UFO for one tick
  (define/public (move/tick)
     (set! x (+ x dx)))

  ;; UFO Image -> Image
  ;; add this UFO to the given scene
  (define/public (render s)
    (place-image UFO x y s))
 ... ))
```

plus Kathryn Gray (Cambridge) & Viera Proulx (NEU)

Imperative Objects

```
(define ufo%
  (class object%
   (init-field x y dx dy))
   ;; UFO = (make-ufo Nat Nat Integer Integer)
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   ;; UFO Image -> Image
   ;; add this UFO to the given scene
   (define/public (render s)
     (place-image UFO x y s))
  ... ))
```

plus an imperative OS library

plus Kathryn Gray (Cambridge) & Viera Proulx (NEU)

Some Conclusions

- functional I/O is a key technology for teaching functional programming at ***all levels, starting with middle school***
- it naturally generalizes to a distributed (concurrent) universe of worlds
- ... and provides a natural path to teaching theorem proving about programs early
- ... and enables a motivated and smooth transition to *imperative* OOP design

Try it out in your languages. It’s easy.

Try it out in your languages. It’s easy.

(2000 lines, when you’re standing on the toes of great co-developers)

The End

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