CS 420 Advanced Programming Languages
Fall Semester, 2022
Doc 12 Clojure Data
Oct 4, 2022

Basic Data Elements

symbols
keywords
literals
lists
vectors
maps
sets

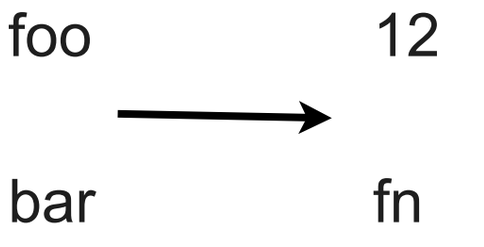
Symbols

Can reference another value

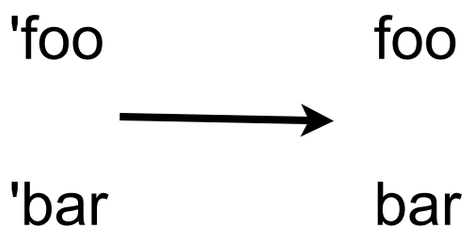
```
(def foo 12)

(defn bar [n] (inc n))
```

When evaluated returns the value



When quoted & evaluated returns it self



Symbols

Can start with any non-numeric character

Can contain alphanumeric characters and ! $ % & * - + = _ | < > ?

```
(def !$%&*-+=_|<>? "wtf")
```

Unicode is supported

```
(def పన్నెండు 12)
(def बारह 12)
(def বার 12)
(def பன்னிரெண்டு 12)
(def ಹನ್ನೆರಡು 12)
(def ਬਾਰ੍ਹਾ 12)
(def बारो 12)
```

Keywords

Like symbols but evaluates to itself

Literal syntax starts with a colon

```
:foobar
:2
:?
:ThisIsALongKeyWordWhichShowsThatTheCanBeLong
```

Colon is part of literal syntax, but not the name of the keyword

```
(= :cat (keyword "cat"))        true
(= :cat (keyword ":cat"))       false
```

Literals - Strings & Characters

"A String"

"Another
string"

(class "cat")
  java.lang.String

\c

\u00ff
  unicode

\o64
  octal

Whitespace Characters

\space
\newline
\formfeed
\return
\backspace
\tab

So what is \n ?

\n verses "\n"

\n	"\n"
Character n	newline in string

(str "a" \n "b" 5)	*"anb5"*
(str "a" \newline "b")	*"a b"*
(str "a" "\n" "b")	*"a b"*

Numbers

Long	Double	Ratio
12	2.11	3/5
0xfe	1.3e-4	
2r111		
5r123		
36rCRAZY		

BigInt	BigDecimal
12N	4.2M

(factorial 100N)

933262154439441526816992388562667004907159682643816214685929638952175999932299156089414639761565182862536979208272237582511852109168640000000000000000000000N

Cast/Convert

byte	(long 12.8)	*12*
short		
int	(rationalize 0.25)	*1/4*
long		
float	(read-string "12.6")	*12.6*
double		
bigdec	*(str 12.3)*	*"12.3"*
bigint		
num		
rationalize		
biginteger		

Collections

Immutable

Heterogeneous

Persistent

Vectors

Sets

Maps

Lists

Queues

Vectors

Expandable, indexed list

Fast insert at end

Expensive insert in front

Fast indexed lookup

[4 "cat" \c]

[4, "cat", \c]

[ ]

Vectors

(vector 8 4 2)	[8 4 2]
(nth [:a :b :c] 2)	:c
(get ["a" "b" "c"] 2)	"c"
(["a" "b" "c"] 2)	"c"
(nth [:a :b :c] 2 "rat")	:c
(nth [:a :b :c] 4 "rat")	"rat"
(.indexOf ["a" "b" "c"] "b")	1
(peek ["a" "b" "c"])	"c"
(pop ["a" "b" "c"])	["a" "b"]
(conj [1 2 3] 4)	[1 2 3 4]
(assoc [1 2 3] 0 9)	[9 2 3]

Accessing Elements - 3 ways

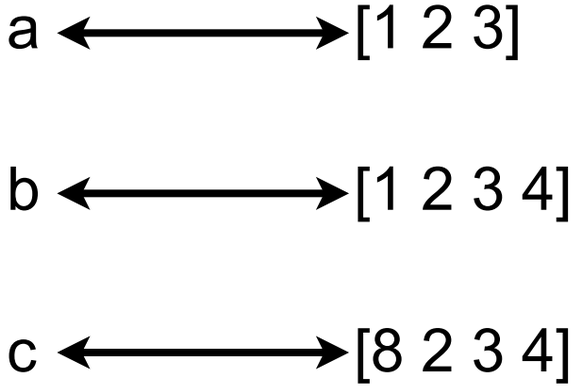
	nth	get	Vector as function
nil vector	Returns nil	Returns nil	Exception
Index out of range	Exception or "Not found" arg	Returns nil	Exception
Not found arg	Yes	Yes	No

Immutability & Persistence

```
(def a  [1 2 3])

(def b  (conj a 4))

(def c  (assoc b 0 8))
```



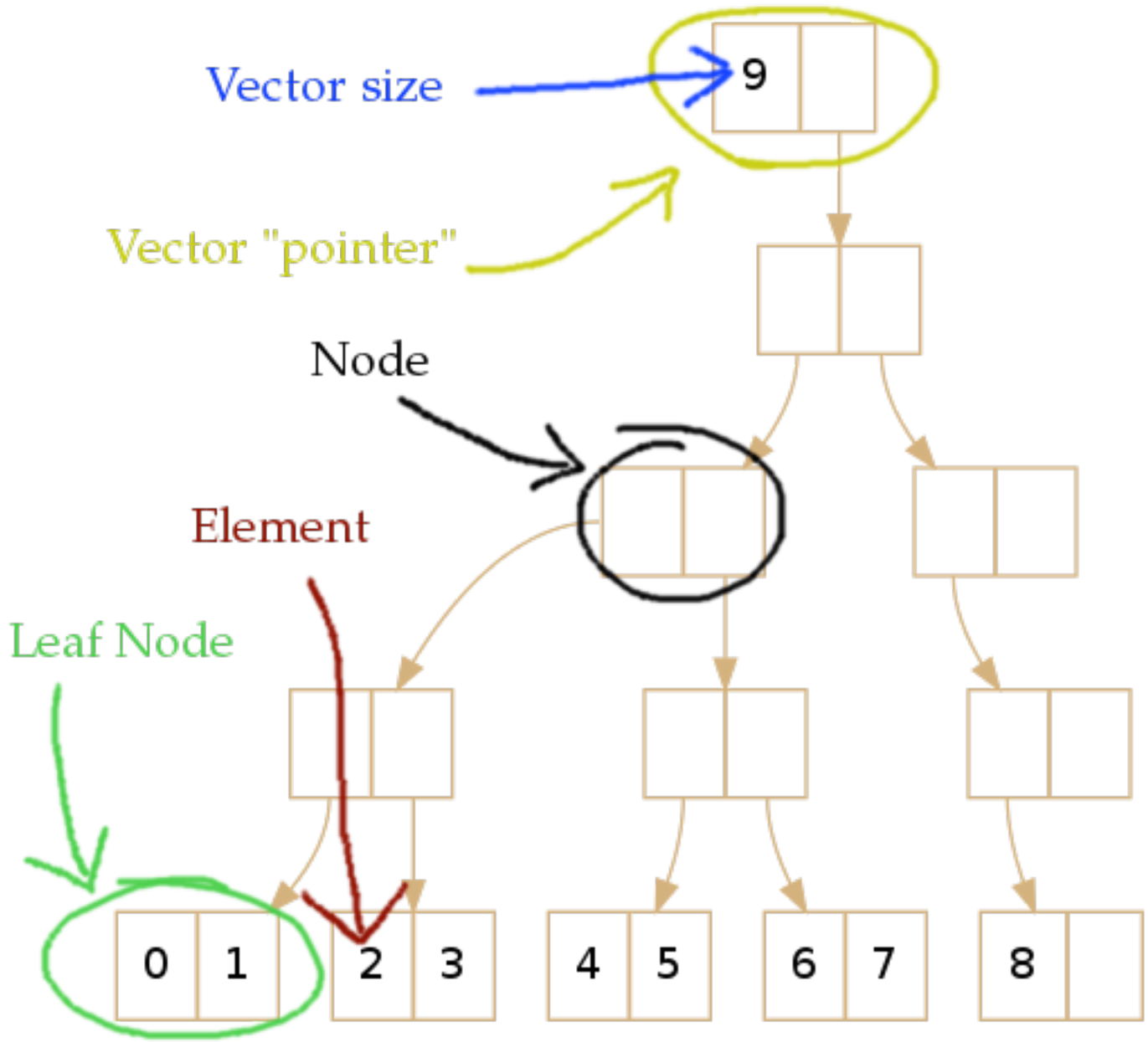

```
Java

int[] d = {1, 2, 3};

d[0] = 8;
```

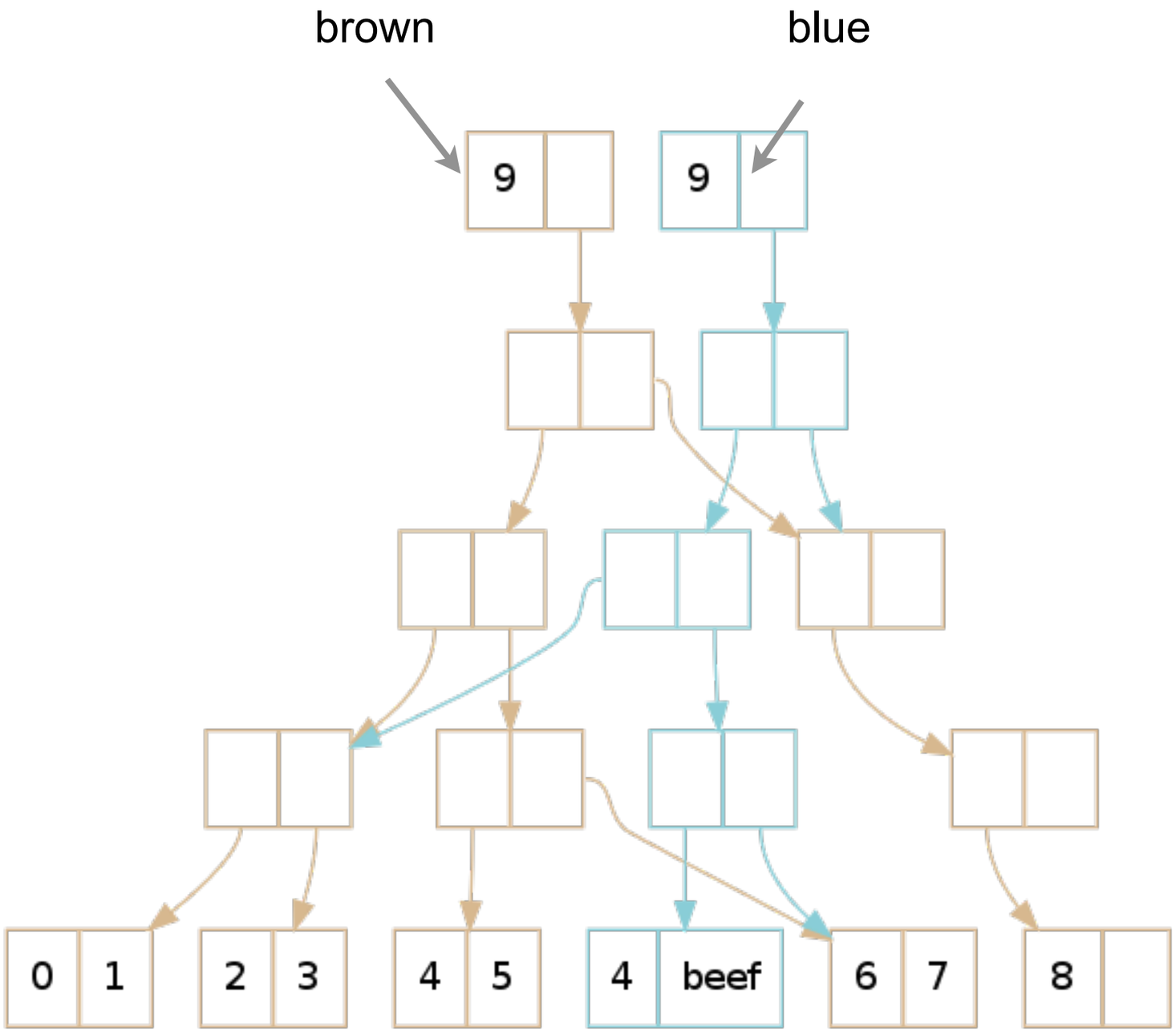
Vector Implementation

(def brown [0 1 2 3 4 5 6 7 8])



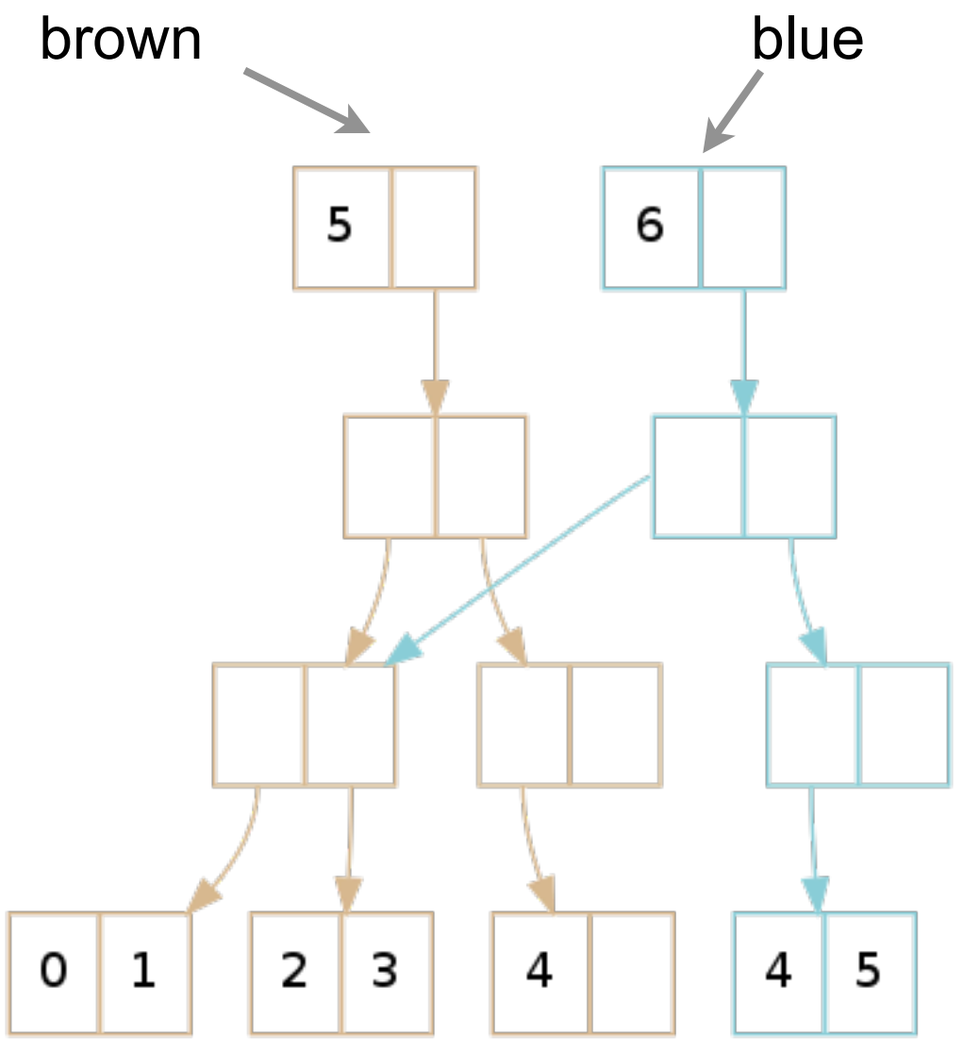
Update

```
(def brown [0 1 2 3 4 5 6 7 8])
(def blue (assoc brown 5 'beef))
```



Adding

(def brown [0 1 2 3 4])
(def blue (conj brown 5)



More Details

Bit-partitioned trie with branching factor of 32

Nodes
  Contain 32 elements

Tree
  Trie on index of elements

1 billion elements
  Tree of depth 6

Some Operation Costs

Operation	Cost
count	O(1)
first	O(<7)
rest	O(<7)
nth	O(<7)
last	O(n)
get	O(<7)
assoc	O(<7)
peek	O(1) ?

For More Details

See

http://hypirion.com/musings/understanding-persistent-vector-pt-1

http://hypirion.com/musings/understanding-persistent-vector-pt-2

Sets

No duplicates

Fast insert & contains

Sets

(contains? #{1 2} 1)	true
(#{2 4} 2)	2
(#{2 4} 3)	nil
(get #{1 2} 1)	1
(get #{1 2} 3)	nil
(get #{1 2} 3 :not-found)	:not-found
(nth #{4 2} 2)	2
(conj #{ 1 2 } 3 4 5)	#{1 2 3 4 5}
(disj #{1 2 3} 2)	#{1 3}
(clojure.set/intersection #{1 2 3} #{2 4 8})	#{2}

Maps (Hash Table)

Key-value map

Keys - any value

Values - any value

Fast insert & find

Very common

```
{:first-name "Roger"
 :last-name "Whitney" }
```

```
{:first-name "Roger",
 :last-name "Whitney" }
```

```
{:name {:first "Roger" :last "Whitney" }
 :phone-numbers
  ["111-2222" "222-3333"]}
```

```
{ "a" 1, 2 "b", [4 3] :me}
```

Maps (Hash Table)

(get {:a 1} :a)	1
({:a 1} :a)	1
(:a {:a 1})	1
({2 "b"} 2)	"b"
(2 {2 "b"})	Error
(conj {:a 1 :b 2} {:a 3} {:c 4})	{:c 4, :a 3, :b 2}
(merge {:a 1 :b 2} {:a 3 :c 4})	{:c 4, :a 3, :b 2}
(assoc {:a 1 :b 2} :a 3 :c 4)	{:c 4, :a 3, :b 2}

Naming Conventions

Clojure	Java
all-lower-case words-separated-by-hyphen	camelCase

```
(.indexOf ["a" "b" "c"] "b")
```

Lists

Linked List

Fast insert & remove at front

'(1 2 3)

'("cat" {:a 1})

'(+ 1 2)

Lists

(list 8 4 2)	(8 4 2)
(nth '("a" "b" "c") 2)	"c"
('("a" "b" "c") 2)	Error
(.indexOf '("a" "b" "c") "b")	1
(peek '("a" "b" "c"))	"a"
(pop '("a" "b" "c"))	("b" "c")
(conj '(1 2 3) 4)	(4 1 2 3)
(class '(1))	clojure.lang.PersistentList

Why the Single Quote

'(+ 1 2) verses (+ 1 2)

All Clojure programs are just lists

Reader/interpreter/compiler evaluates all lists

Single quote turns off evaluation of the list

Homoiconicity - Code-as-Data

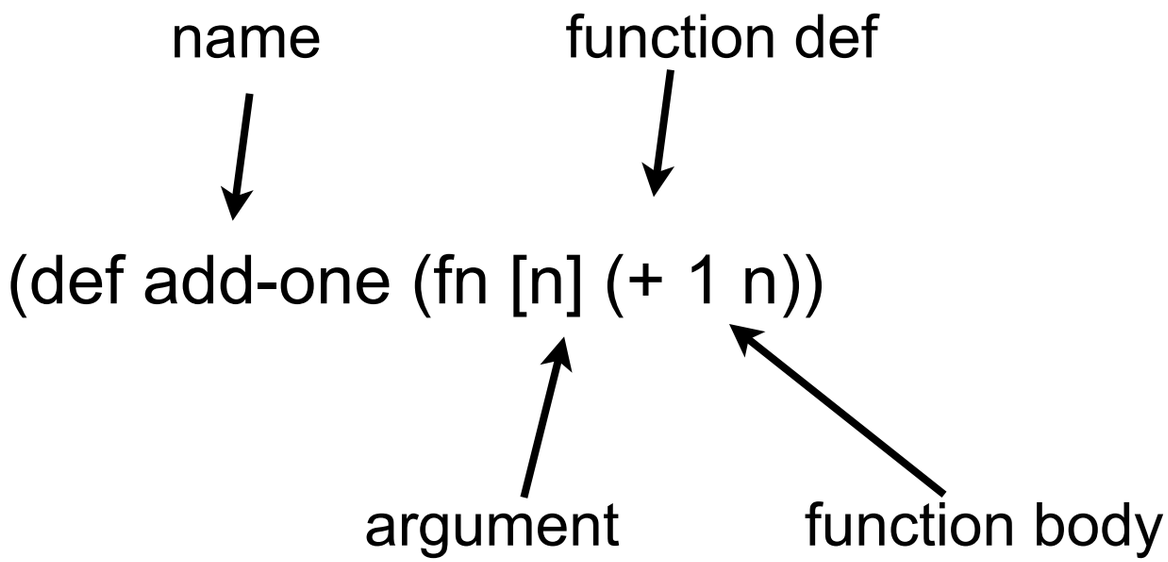
Clojure programs are represented by Clojure data structures

List structure is the Clojure syntax

Makes it easy for Clojure programs to modify Clojure programs

Macros

Defining a function



(add-one 5)

Defining a function - Compact version

```
(def add-one (fn [n] (+ 1 n)))
```

```
(defn add-one
  [n]
  (+ 1 n))
```

```
(add-one 5)
```

Valid function names

Function definitions are just Clojure data structures

Function names are just symbols

So any valid symbol can be used as a function name

```
(defn பன்னிரெண்டு-சேர்க்க
  [n]
  (+ 12 n))
```

Multiple Arguments

```
(defn sum
   [a b c d]
   (+ a b c d))
```

```
(defn foo-bar
   [a b]
   (if (< a b)
      "smaller"
      (+ a b)))
```

defn Format

```
(defn function-name
  "Doc string"
  [arg1 arg2 … argN]
  (form1)
  (form2)
  …
  (formN))
```

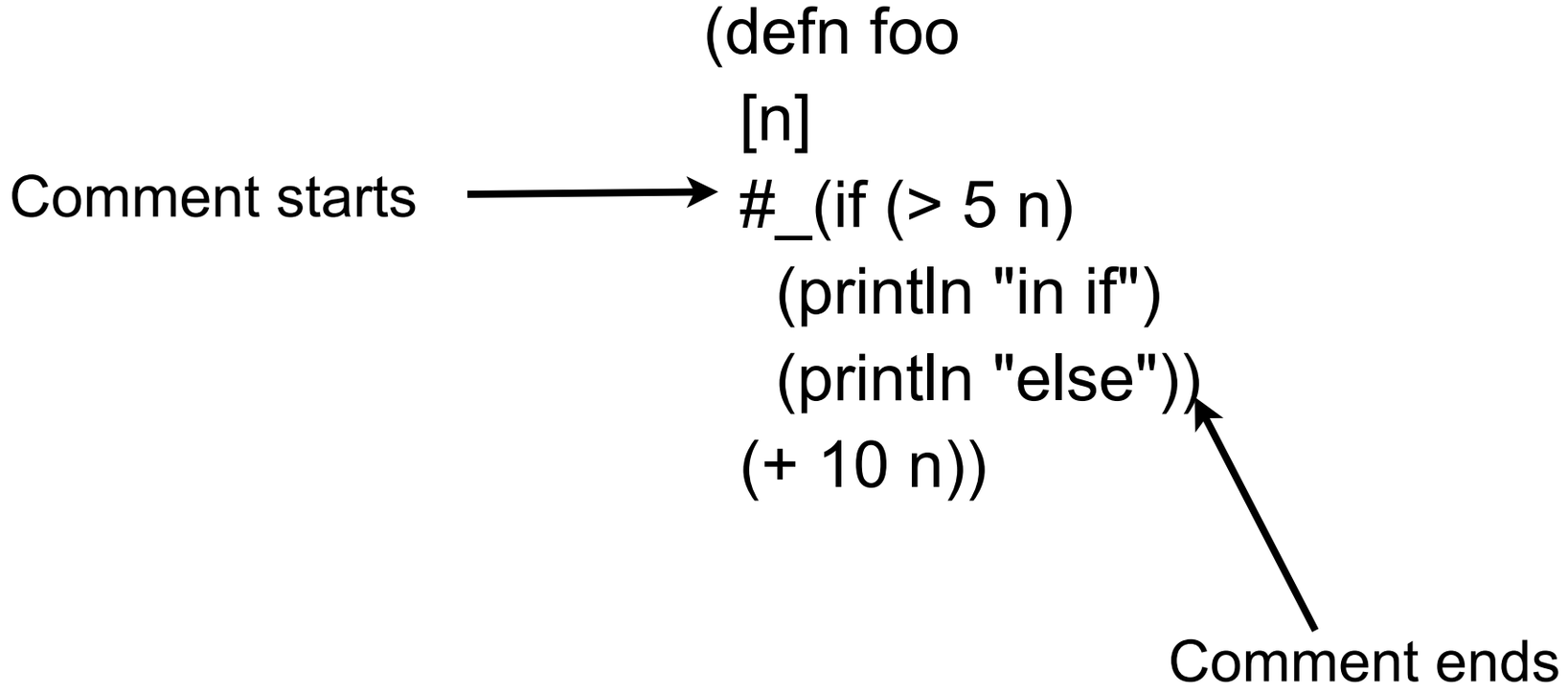
Doc Strings

(doc pop) (clojure.repl/doc pop)	Prints doc string in REPL
(find-doc "pop") (clojure.repl/find-doc "pop"	Finds functions related to "pop"

Comments

; a semi-colon starts a comment that goes to end of the line

#_ when prepended to a form makes the entire form a comment



Explain This

```
(defn foo
  [n]
  "How does this work? Not a compile error."
  (if (> 5 n)
    (println "in if")
    (println "else"))
  "This is not a doc comment"
  (+ 10 n))
```

And This?

```
(defn foo
  [n]
  (if (> 5 n)
    "What happens now?"
    (println "in if")
    (println "else"))
"This is not a doc comment"
(+ 10 n))
```

Recall

```
(defn function-name
  "Doc string"
  [arg1 arg2 … argN]
  (form1)
  (form2)
  …
  (formN))
```

Anonymous Function - Lambda

Function not bound to symbol

(fn [args] (form1) (form2)…(formn))

(fn [a b] (< (first a) (first b)))

((fn [a b] (< (first a) (first b))) [2 3] [5])

```
((fn [a b]
   (println a  b)
   (< (first a) (first b))) [2 3] [5])
```

Short Syntax for Lambda

```
(fn [a b] (< (first a) (first b)))
```

```
#(< (first %1) (first %2))
```

%n -> n'th argument

```
#(+ 2 %)
```

if only one argument can use %

Passing Functions as Arguments

```
(sort < [3 1 2])

(sort > [3 1 2])

(sort (fn [a b] (< a b))  [3 1 2])

(sort #(< %1 %2)  [3 1 2])

(sort (fn [a b] (compare (str a) (str b))) [ 4 3 16])

(sort  #(compare (str %1)  (str %2))  [4 3 16])
```

Closure

function + reference to its environment

```
(defn adder
  [n]
  #(+ n %))

(def add-5 (adder 5))

(add-5 10)                    Returns 15
```