CS 596 Functional Programming and Design
Fall Semester, 2014
Doc 10 BST, Manipulating Functions
Oct 7, 2014

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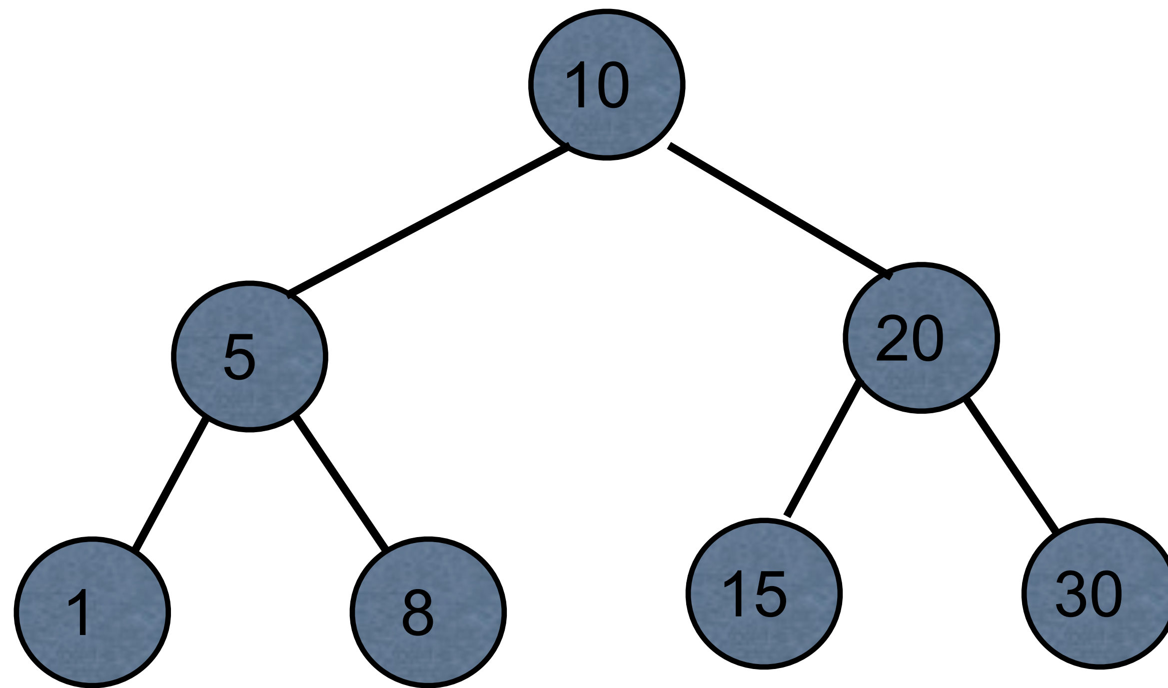
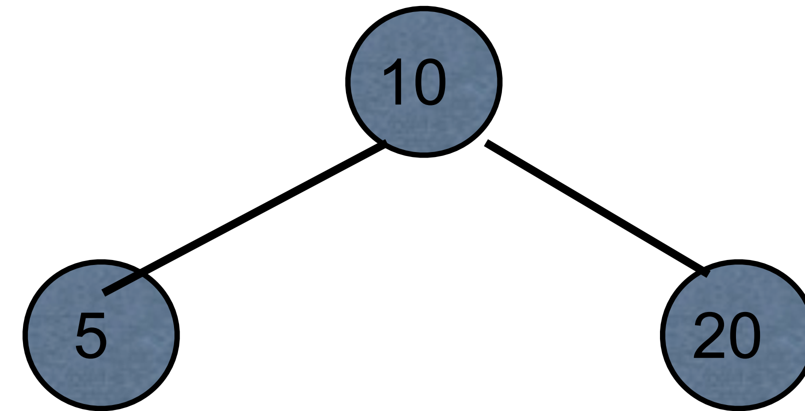
Binary Search Tree



Data structure books only show keys at each node

But each node has a key and a value

Representing a Tree



[10 [5 nil nil] [20 nil nil]]

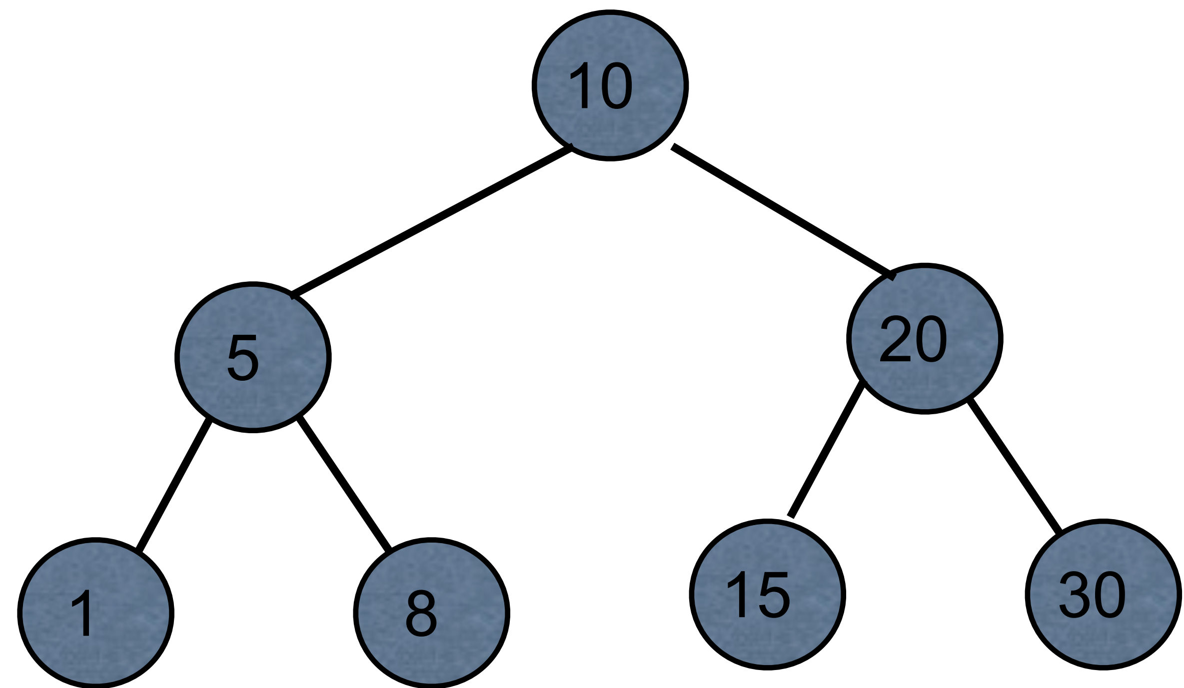
[[5 nil nil] 10 [20 nil nil]]

{:key 10, :left {:key 5 }, :right {:key 20}}

{:key 10 :value foo
:left {:key 5 :value bar}
:right {:key 20 :value foo-bar}}

We will see other ways to represent a tree

Representing Tree



[key left right]

(def tree [10 [5 [1 nil nil] [8 nil nil]] [20 [15 nil nil] [30 nil nil]]])

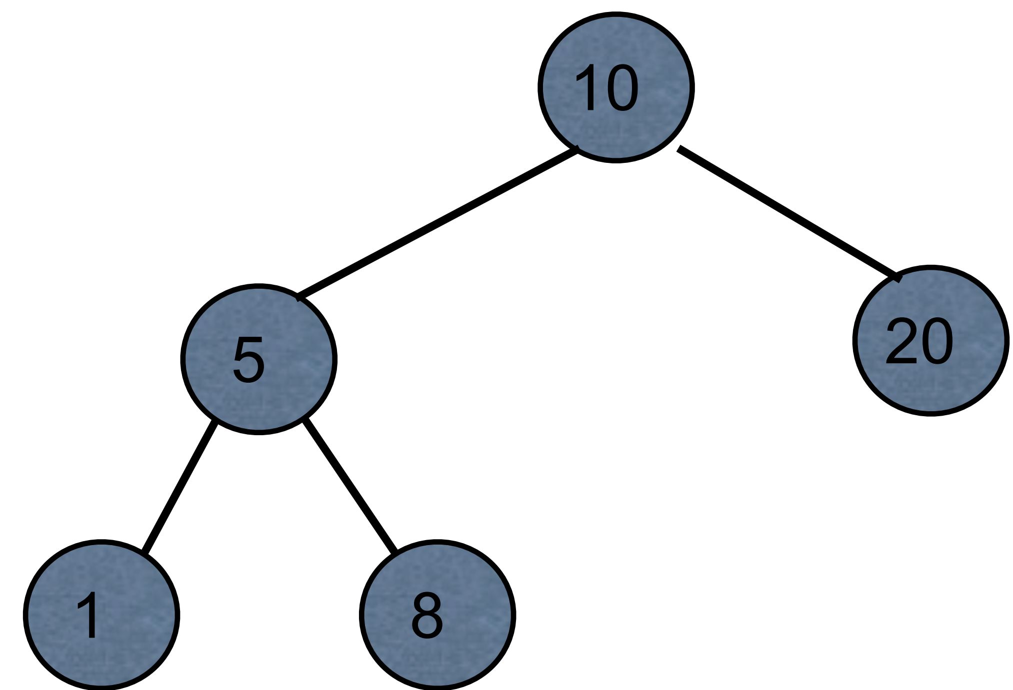
Hiding the Structure of Node

```
(defn left-child
 [node]
 (node 1))

(defn right-child
 [node]
 (node 2))

(defn value
 [node]
 (node 0))
```

Navigating the Tree




```
(def large-tree [10 [5 [1 nil nil] [8 nil nil]] [20 nil nil]])
```

```
(right-child (left-child large-tree))
```

```
(-> large-tree
    left-child
    right-child)
```

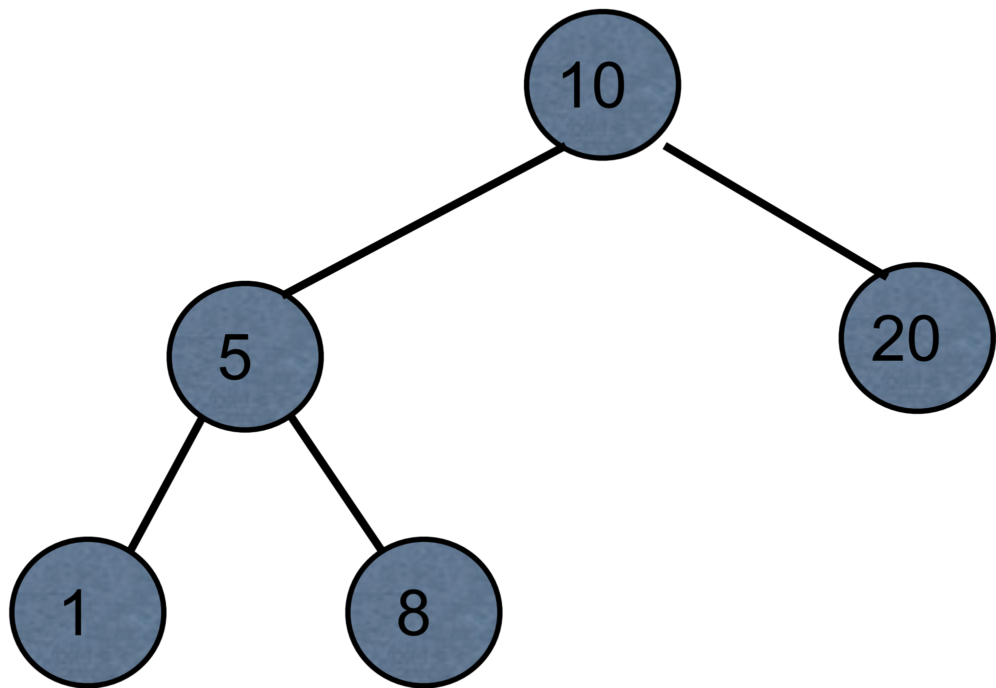
Standard Search

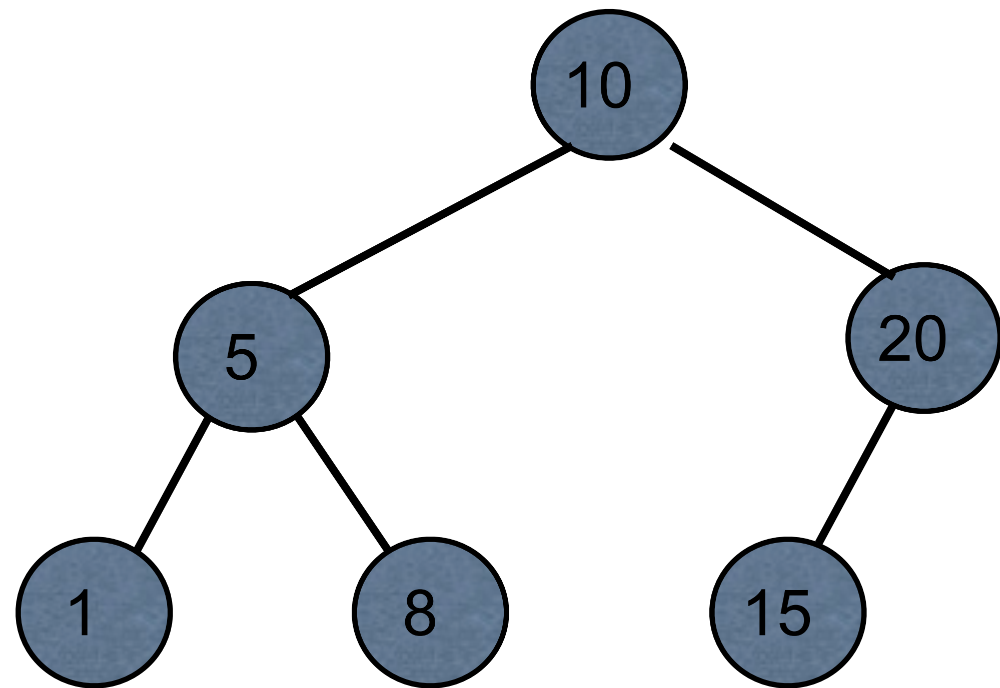
```
(defn find-key
      [tree k]
      (let [left (left-child tree)
                right (right-child tree)
                value (value tree)]
            (cond
                  (= k value) k
                  (and left (< k value))  (find-key left k)
                  (and right (> k value)) (find-key right k)
                  :default nil)))
```

This is where you really want a key & value at each node of the tree

Inserting

Add 15

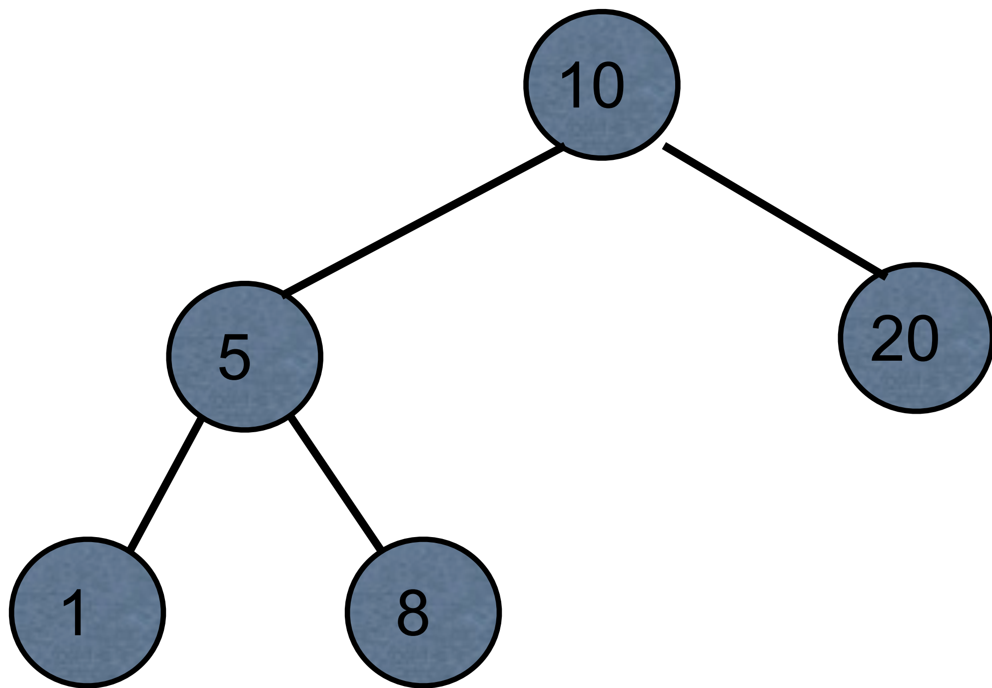


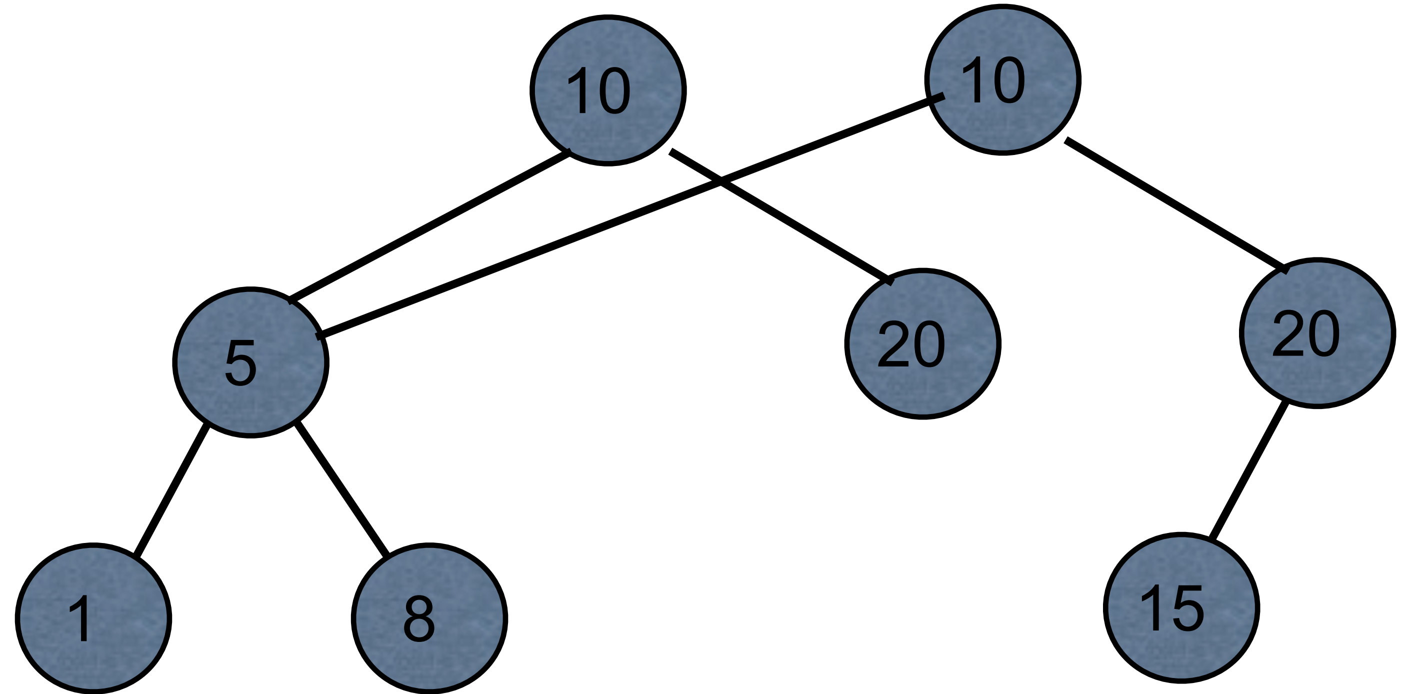


But we have persistence & immutability

Inserting

Add 15





Inserting - Three Ways

Build the tree as you traverse the tree

Find path to node and use assoc-in

Use a zipper

Build Tree as Traverse

Tree node {:left left-child :value value :right right-child}

```
(defn make-tree
  [lelft value right]
  {:left left :val value :right right})
```

```
(defn insert [tree value]
  (if-let [member (:value tree)]
    (cond
      (< value member) (make-tree (insert (:left tree) value) member (:right tree))
      (> value member) (make-tree (:left tree) member (insert (:right tree) value))
      :else tree)
    (make-tree nil value nil)))
```


From https://github.com/leonardoborges/purely-functional-data-structures/blob/master/src/purely_functional_data_structures/ch2.clj

assoc-in

Associates a value in a nested structure

```
(def users [{:name "James" :age 26}  {:name "John" :age 43}])

(assoc-in users [1 :age] 44)

                    [{:name "James", :age 26} {:name "John", :age 44}]

(assoc-in users [1 :password] "nhoJ")

                    [{:name "James", :age 26} {:password "nhoJ", :name
                    "John", :age 43}]
```

```
(def tree [10 [5 [1 nil nil] [8 nil nil]] [20 [15 nil nil] [30 nil nil]]])
```

```
(defn position-of
  "Return path to k in tree"
    [tree k]
    (let [left (left-child tree)
            right (right-child tree)
            value (value tree)]
        (cond
            (= k value)              nil
            (and left (< k value))  (cons 1 (position-of left k))
            (< k value)              [1]
            (and right (> k value)) (cons 2 (position-of right k))
            (> k value)              [2])))
```

```
(position-of tree 10)     nil
(position-of tree 5)      (1)
(position-of tree 1)      (1 1)
(position-of tree 8)      (1 2)
(position-of tree 20)     (2)
(position-of tree 15)     (2 1)
(position-of tree -1)     (1 1 1)
```

Insert

```
(defn bst-insert
      [tree value]
      (assoc-in tree (position-of tree value) [value nil nil]))
```

```
(def small-tree [10 nil nil])
```

```
(bst-insert small-tree 5)
```

[10 [5 nil nil] nil]

```
(-> small-tree
    (bst-insert 5)
    (bst-insert 20)
    (bst-insert 1))
```

[10 [5 [1 nil nil] nil] [20 nil nil]]

Zippers

Allow you to navigate & change structures

seq-zip
vector-zip
xml-zip

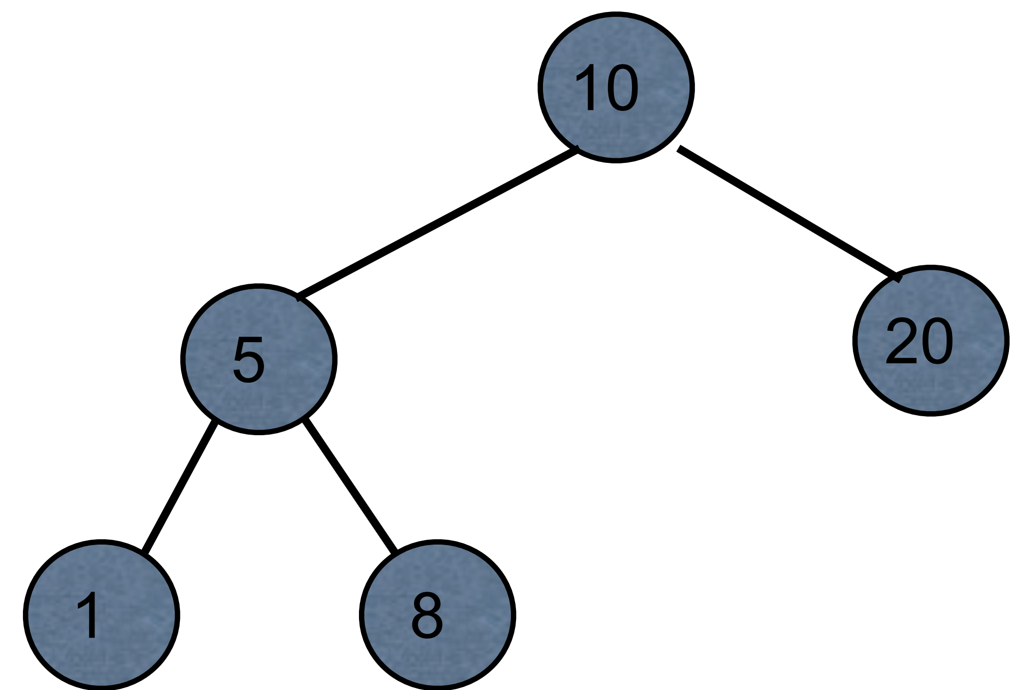
Keeps pointer to current location in structure

Moving
up, down, left, right, next, prev, leftmost, rightmost

Accessing structure
node, root

Editing
remove, replace, edit, insert-child

Zipper Examples




```
(ns basiclectures.basic-language.zip
  (:require [clojure.zip :as zip] ))
(def large-tree [10 [5 [1 nil nil] [8 nil nil]] [20 nil nil]])
```

```
(-> large-tree
    zip/vector-zip
    zip/node)
```

[10 [5 [1 nil nil] [8 nil nil]] [20 nil nil]]

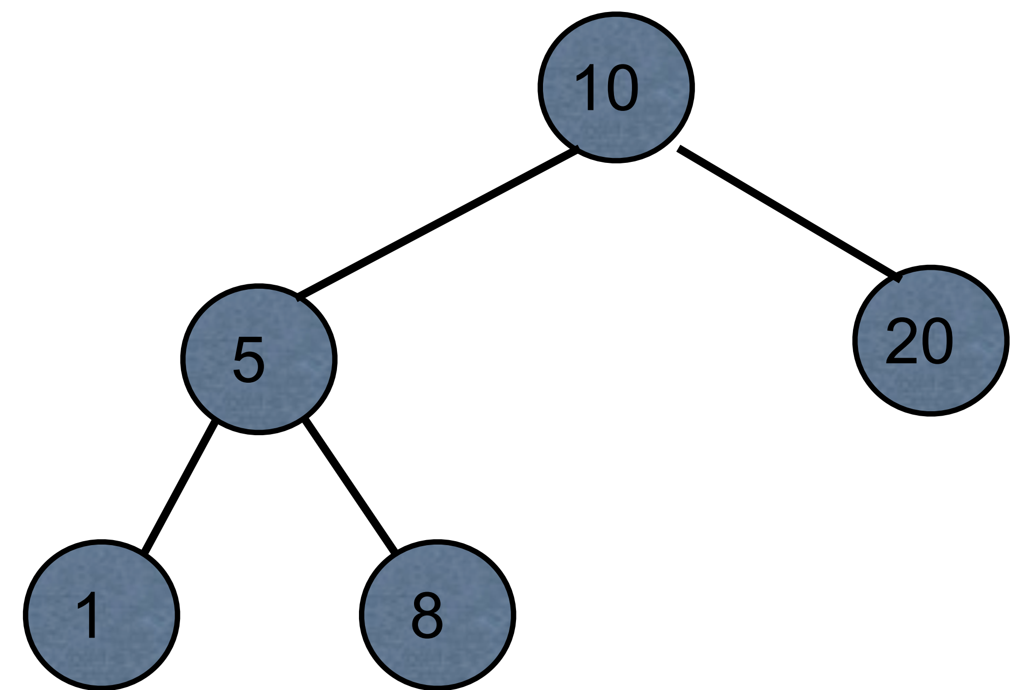
```
(-> large-tree
    zip/vector-zip
    zip/down
    zip/node)
```

10

```
(-> large-tree
    zip/vector-zip
    zip/down
    zip/right
    zip/node)
```

[5 [1 nil nil] [8 nil nil]]

Zipper Examples




```
(ns basiclectures.basic-language.zip
  (:require [clojure.zip :as zip] ))
(def large-tree [10 [5 [1 nil nil] [8 nil nil]] [20 nil nil]])
```

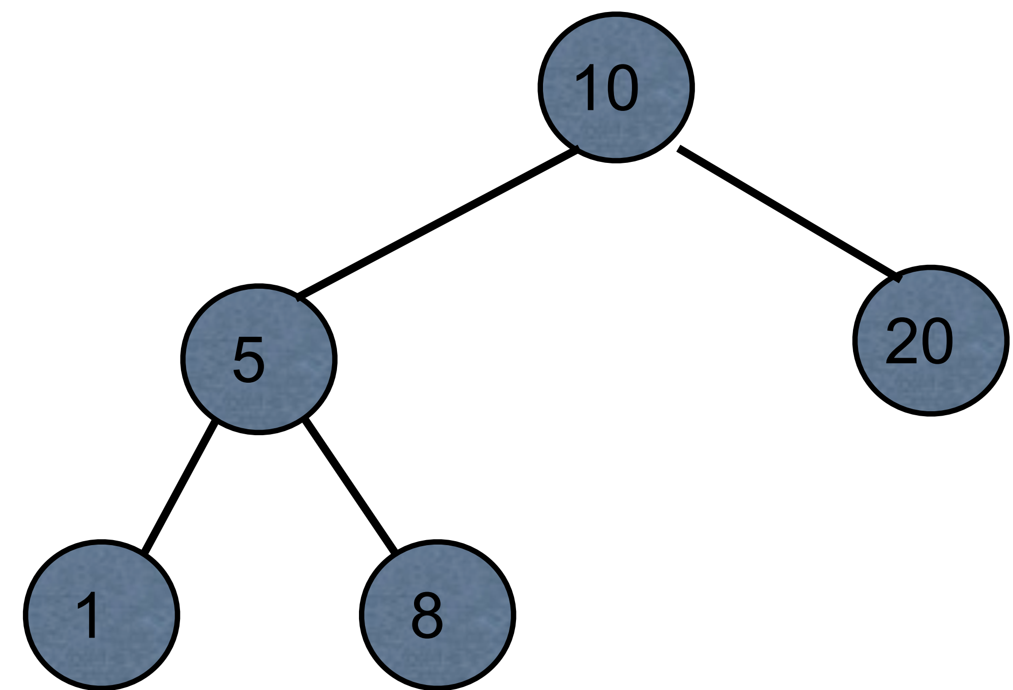
```
(-> large-tree
    zip/vector-zip
    zip/down
    zip/right
    zip/right
    zip/node)
```

[20 nil nil]

```
(-> large-tree
    zip/vector-zip
    zip/down
    zip/right
    zip/down
    zip/node)
```

5

Zipper Examples

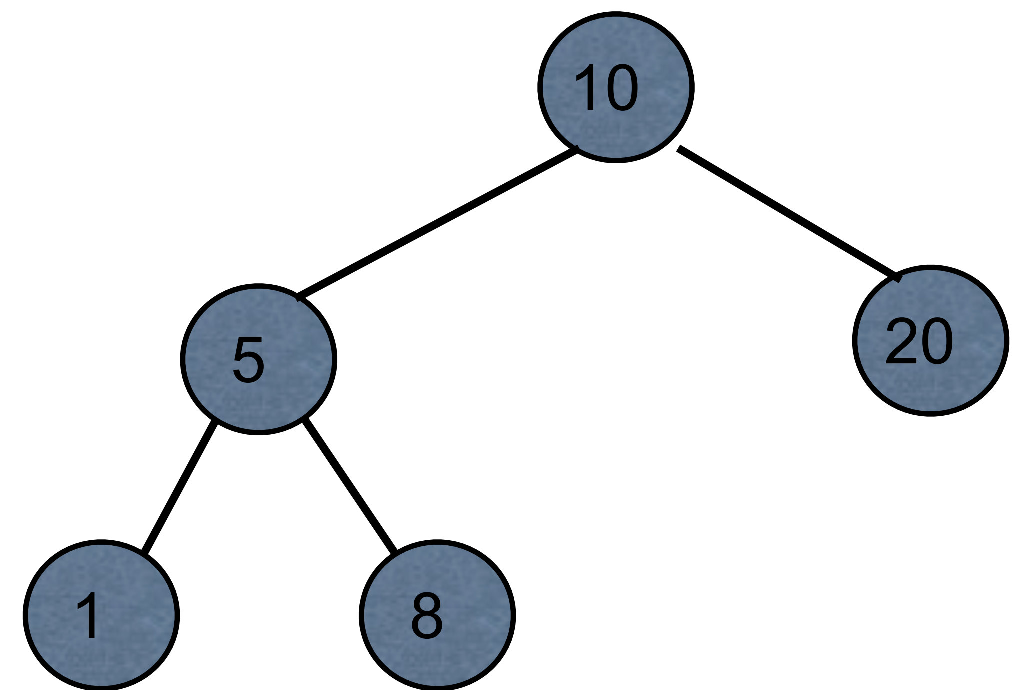



```
(ns basiclectures.basic-language.zip
  (:require [clojure.zip :as zip] ))
(def large-tree [10 [5 [1 nil nil] [8 nil nil]] [20 nil nil]])
```

```
(-> large-tree
    zip/vector-zip
    zip/down
    zip/right)
```

```
[[5 [1 nil nil] [8 nil nil]] {:l [10], :pnodes [[10 [5 [1 nil nil]
[8 nil nil]] [20 nil nil]]], :ppath nil, :r ([20 nil nil])}]
```

Zipper Examples

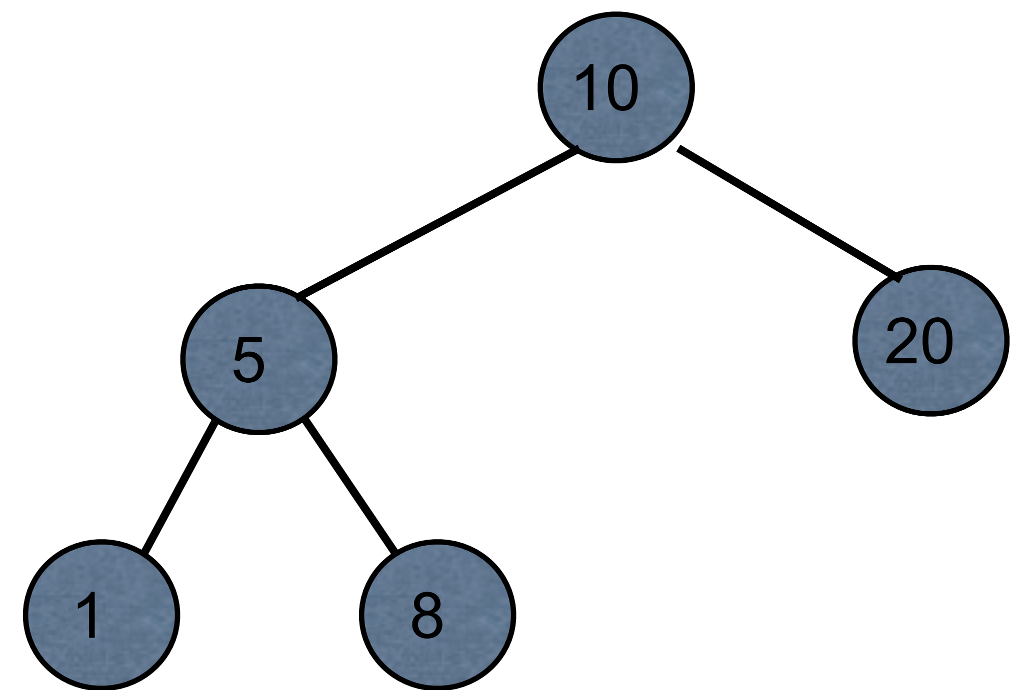



```
(ns basiclectures.basic-language.zip
  (:require [clojure.zip :as zip] ))
(def large-tree [10 [5 [1 nil nil] [8 nil nil]] [20 nil nil]])
```

```
(-> large-tree
    zip/vector-zip
    zip/down
    zip/right
    zip/right
    (zip/replace [50 nil nil])
    zip/root)
```

```
[10 [5 [1 nil nil] [8 nil nil]] [50 nil nil]]
```

Zipper Examples




```
(ns basiclectures.basic-language.zip
  (:require [clojure.zip :as zip] ))
(def large-tree [10 [5 [1 nil nil] [8 nil nil]] [20 nil nil]])
```

```
(-> large-tree
    zip/vector-zip
    zip/down
    (zip/replace 11)
    zip/root)
```

```
[11 [5 [1 nil nil] [8 nil nil]] [20 nil nil]]
```

BST Insert with Zipper

[key left right]   Tree representation

Accessing

```
(defn zipper->left-child
  [zipper]
  (-> zipper zip/down zip/right))

(defn zipper->right-child
  [zipper]
  (-> zipper zip/down zip/rightmost))

(defn zipper->value
  [zipper]
  (if (zip/node zipper)
    (-> zipper zip/down zip/node)
    nil))
```

Replacing/Testing

```
(defn replace-node
  [zipper replacement]
  (let [location (zip/node zipper)
        node (zip/make-node zipper location [replacement nil nil])]
    (-> zipper (zip/replace node) zip/root)))

(defn tree-empty?
  [zipper]
  (not (zip/node zipper)))
```

The Insert

```
(defn bst-zipper-insert
  [zipper x]
  (let [value (zipper->value zipper)]
    (cond
      (tree-empty? zipper) (replace-node zipper x)
      (= x value) (zip/root zipper)
      (< x value) (recur (zipper->left-child zipper) x)
      (> x value) (recur (zipper->right-child zipper) x))))


(defn bst-insert
  [tree x]
  (bst-zipper-insert (zip/vector-zip tree) x))
```

BST as Maps & Zippers

Zippers are defined for

- XML
- vectors
- seq

What about other structures?

```
{:left {:value 5 :left nil :right nil} :value 10 :right {:value 15 :left nil :right nil}}
```

Can define zippers on other types

Making New Zippers

(zipper branch? children make-node root)

branch?

One argument - node

Returns true if node can have children

children

One argument - node

Returns sequence of the node's children

make-node

Two arguments - Existing node, seq of children

Returns new node from the children

Root

Root of the structure

Zipper for BST as a map

```
{:left {:value 5 :left nil :right nil} :value 10 :right nil}
```

branch?

```
map?
```

children

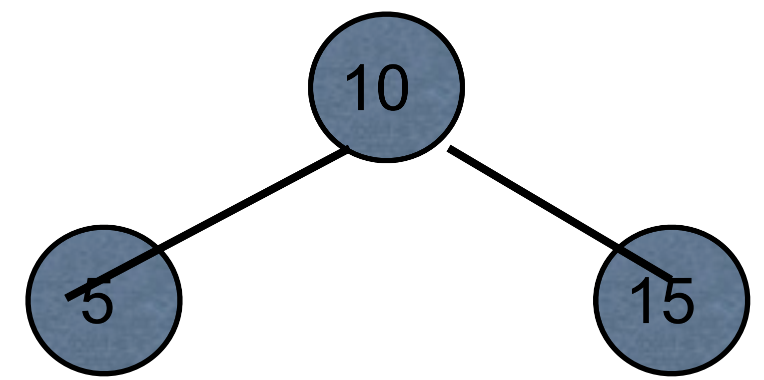
```
(defn tree->children
  [map]
  [(:value map) (:left map) (:right map)])
```

make-node

```
(defn children->tree
  [_ sequence]
  {:value (first sequence)
   :left (second sequence)
   :right (last sequence)})
```

Order has to match that in tree->children

Using the Zipper




```
(def map-tree {:left {:value 5 :left nil :right nil} :value 10 :right {:value 15 :left nil :right nil}})
```

```
(def map-zipper (zip/zipper map? tree->children children->tree map-tree))
```

```
(-> map-zipper
   zip/down
   zip/right
   zip/node)
```

```
{:value 5, :left nil, :right nil}
```

Doing insert in BST as map

```
(defn bst-map-insert
  [tree x]
  (bst-zipper-insert
    (zip/zipper map? tree->children children->tree tree)
    x))
```

Notice the repeat

```
(zip/zipper map? tree->children children->tree tree)
```

Once we figure out the needed functions would like to forget about it

```
(defn bst-map-zipper
   [tree-map]
    (zip/zipper map? tree->children children->tree tree-map)
```

Shorter Way - partial

```
(defn bst-map-zipper  (partial zip/zipper map? tree->children children->tree)
```

```
(partial f arg1 arg2 … argk)
```

f - function with n > k arguments

arg1 arg2 … argk - first k arguments of f

Return function that needs n - k arguments

Examples

```
(def hundred-times (partial * 100))
(hundred-times 5)                                  500

(hundred-times 5 4)                                2000



(reduce + (take-while (partial > 1000) (iterate inc 0)))        499500



(def to-english (partial clojure.pprint/cl-format nil "~@(~@[~R~]~^ ~A.~)"))

(to-english 123456)

                 "One hundred twenty-three thousand, four hundred fifty-six"
```

Currying

Currying

Multi-argument function -> chain of single-argument functions

```
adder(a, b c) {a + b + c;}

addA = adder.curry();
addB = addA(2);
addC = addB(3);
answer = addC(4);
```

Manipulating Functions

juxt

Combines a set of functions

Returns vector applying each function to input

```
(def basic-math (juxt + - * /))
(basic-math 2 5)
```

[7 -3 10 2/5]

```
(def split-collection (juxt take drop))
(split-collection 4 (range 9))
```

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

juxt

```
((juxt :last :first) {:last "Adams" :first "Zak"} )
```

```
["Adams" "Zak"]
```

```
(sort-by (juxt :last :first) [{:last "Adams" :first "Zak"}
                              {:last "Zen" :first "Alan"}
                              {:last "Smith" :first "Alan"}])
```

```
({:last "Adams", :first "Zak"}
 {:last "Smith", :first "Alan"}
 {:last "Zen", :first "Alan"})
```

```
(sort-by (juxt :first :last) [{:last "Adams" :first "Zak"}
                    {:last "Zen" :first "Alan"}
                    {:last "Smith" :first "Alan"}])
```

```
({:last "Smith", :first "Alan"}
 {:last "Zen", :first "Alan"}
 {:last "Adams", :first "Zak"})
```

comp

Takes a sequence of functions
Composes the functions

((comp str +) 8 8 8) "24"

(def fourth (comp first rest rest rest))

(fourth [:a :b :c :d :e]) :d

sdsu-nth

Given n can we produce

(comp first rest rest rest … rest)

where we have n -1 rest's?

Yes We Can!

```
(defn fnth
  [n]
  (apply comp
         (cons first
               (take (dec n) (repeat rest)))))
```

```
((fnth 1) [:a :b :c :d :e])          :a
((fnth 3) [:a :b :c :d :e])          :c
```


Example from Joy of Clojure, Second Edition

How does this work?

```
(repeat rest)
```

infinite lazy sequence of rest

```
(take (dec n) (repeat rest))
```

'(rest rest … rest)   ;n-1 rest's

```
(cons first
      (take (dec n) (repeat rest)))
```

'(first rest rest … rest)

```
(apply comp
       (cons first
             (take (dec n) (repeat rest))))
```

(comp first rest rest … rest)

memoize

(memoize f)

Caches results of function f
Uses cached value next time f is called with same arguments

```
(defn adder
  [x]
  (println "adder" x)
  (inc x))

(def adder-memoized (memoize adder))

(adder-memoized 1)          prints 1, returns 2
(adder-memoized 1)          returns 2
(adder-memoized 2)          prints 2, returns 3
(adder-memoized 1)          returns 2
```

memoize - Cache Size

Cache is a map

Contains return values for each different set of input arguments

Delay

Suspends execution of code until delay is dereferenced

Caches result

Second time dereferenced returns cached result

Thread safe

```
(def wait (delay (println "do it now") (+ 1 2)))
```

```
@wait        prints "do it now", returns 3
@wait        returns 3
```

realized?

Returns true if a value has been produced for a promise, delay, future or lazy sequence.

```
(def wait (delay (println "do it now") (+ 1 2)))
```

```
(realized? wait)   false
@wait              prints "do it now", returns 3
(realized? wait)   true
@wait              returns 3
```

Example - Proxy for Expensive Operation

```
(defn fetch-page
  [url]
  {:url url
   :contents (delay (slurp url))})
```

```
(def result (fetch-page "http://www.eli.sdsu.edu/index.html"))

(:contents result)                  #<Delay@2fcc470c: :pending>

(realized? (:contents result))      false

@(:contents result)                 "<!DOCTYPE html>\n<html lang=\"en\">\n …"
```

@ and deref

```
@(:contents result)

(deref (:contents result))
```

Future

Computes body on another thread

Use @ or deref to get answer

@, deref blocks until computation is done

```
(def long-calculation (future (apply + (range 1e8))))
@long-calculation
```

Future & Delay in ending program

When you end your program there will be a 1 minute delay if you used future

End your program with (shutdown-agents)

```
(def long-calculation (future (apply + (range 1e8))))

@long-calculation

(shutdown-agents)
```

(shutdown-agents) & REPL

(shutdown-agents) shuts down your REPL

deref with Timeout

```
(deref (future (Thread/sleep 5000) :done!)
       1000
       :impatient!)
  ;= :impatient!
```

Future

```
(println "[Main] Start")

(def what-is-the-answer-to-life (future
       (println "[Future] started computation")
       (Thread/sleep 3000) ;;
       (println "[Future] completed computation")
       42))

(println "[Main] created future")

(Thread/sleep 1000)
(println "[Main] do other things")
(println "[Main] the result" @what-is-the-answer-to-life)
```