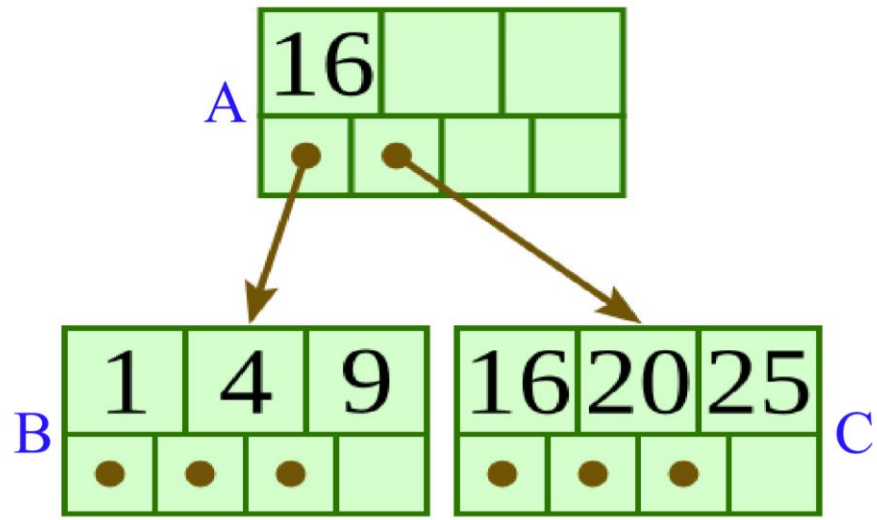
Quiz:
B+ tree

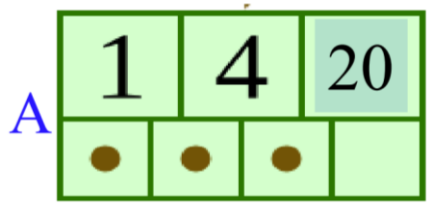
Example B^+-tree of order 4.



Example B^+-tree of order 4,
after inserting 3 values: 20, 1 and 4.

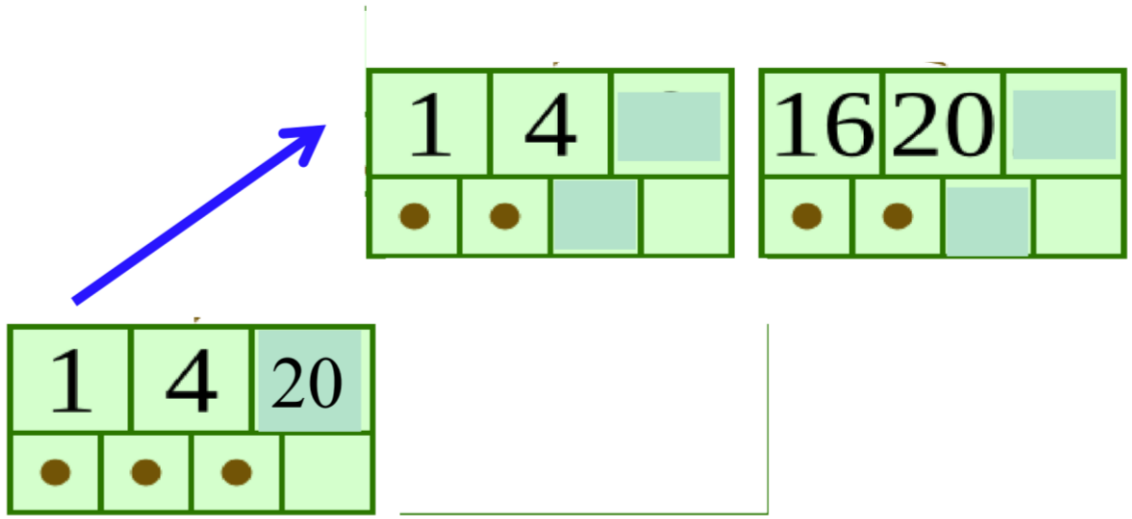
Now insert 16

find;
insert OR
{split; recurse}

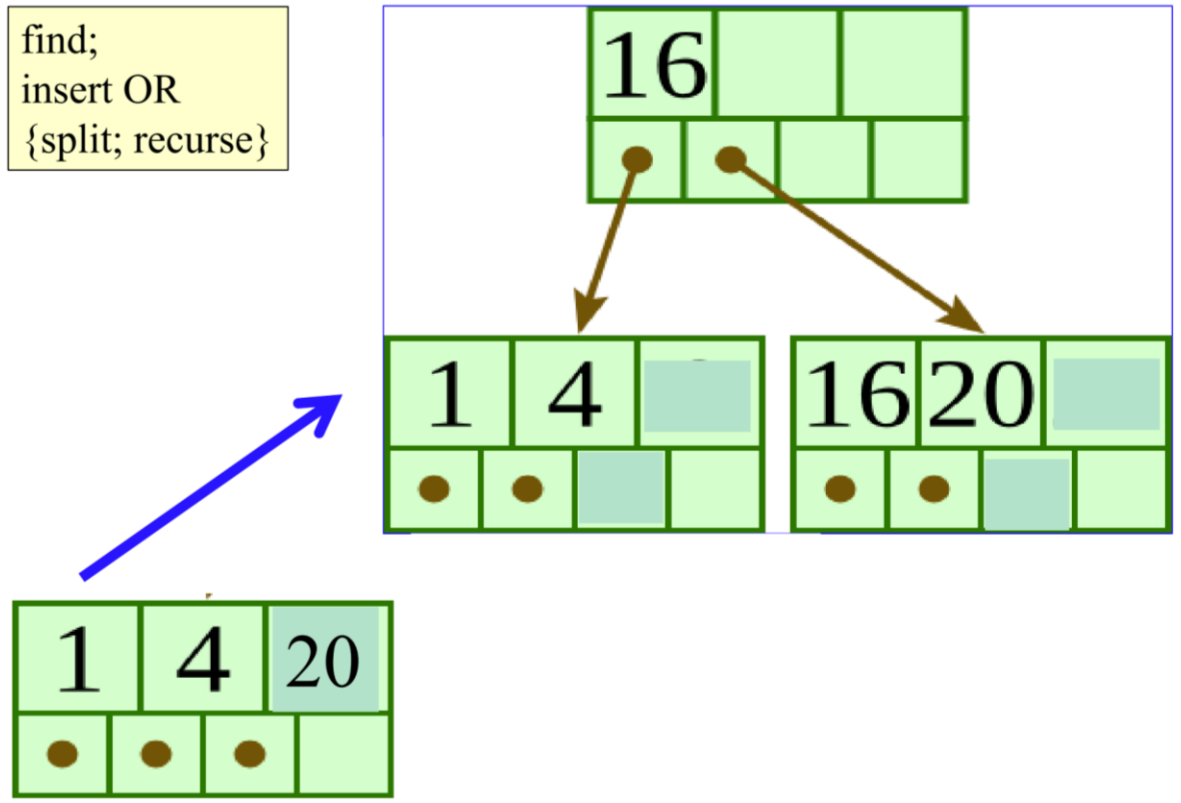


Cont’d …

find;
insert OR
{split; recurse}

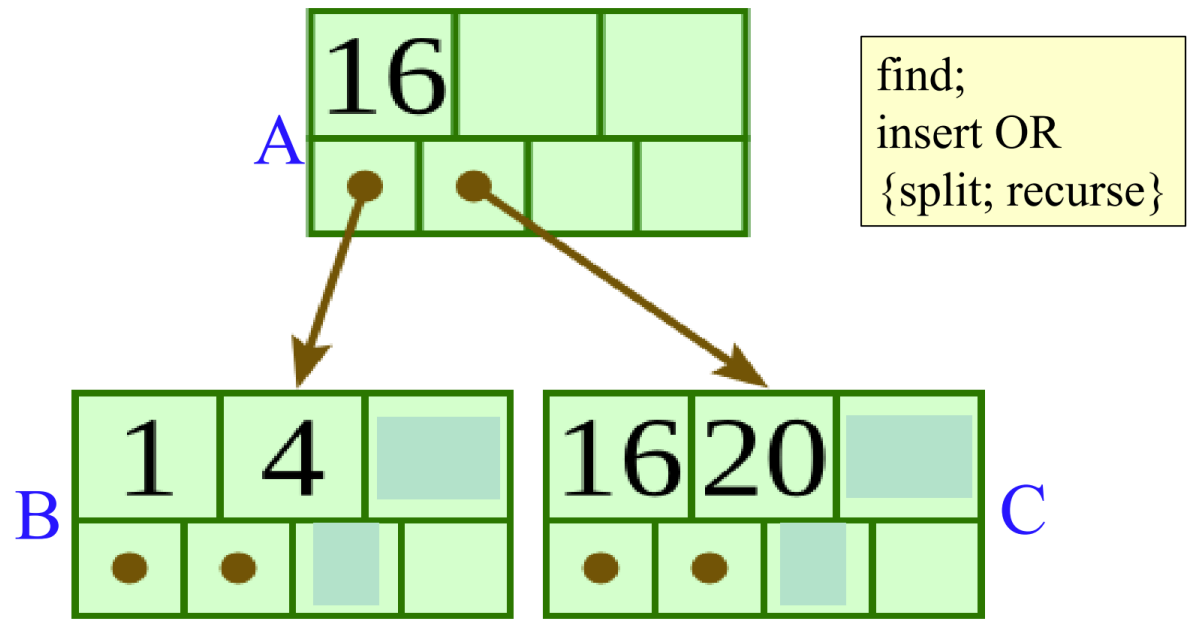


Cont’d …



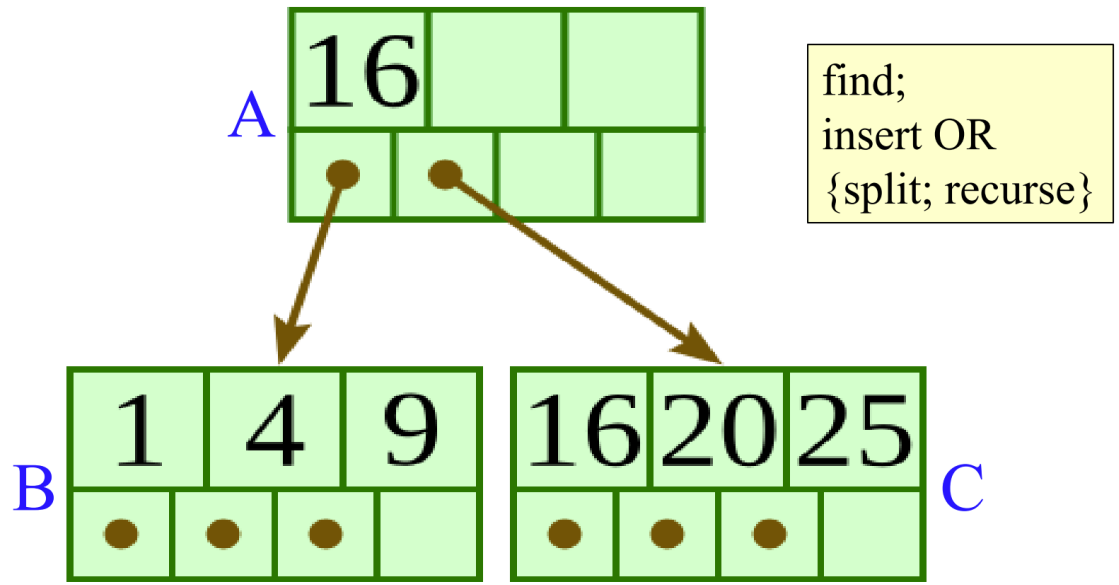
After inserting 16.

Now insert 25, 9

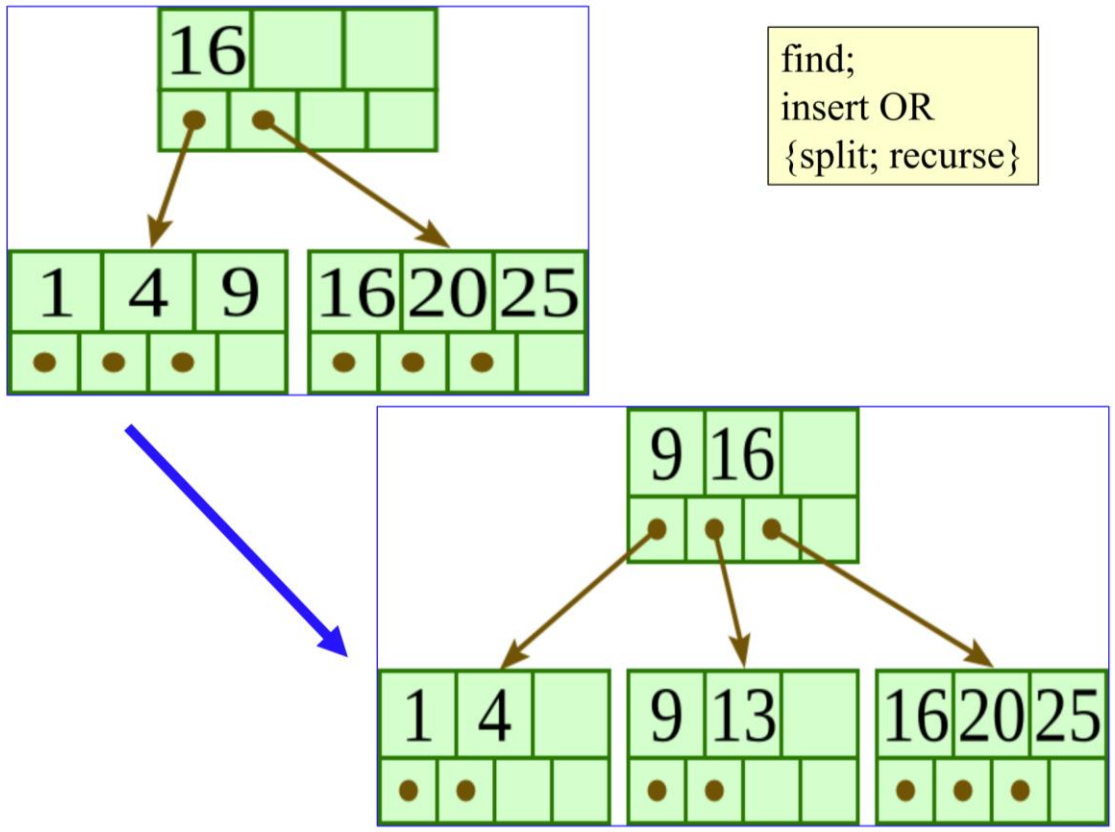


After inserting 25, 9.

Now insert 13

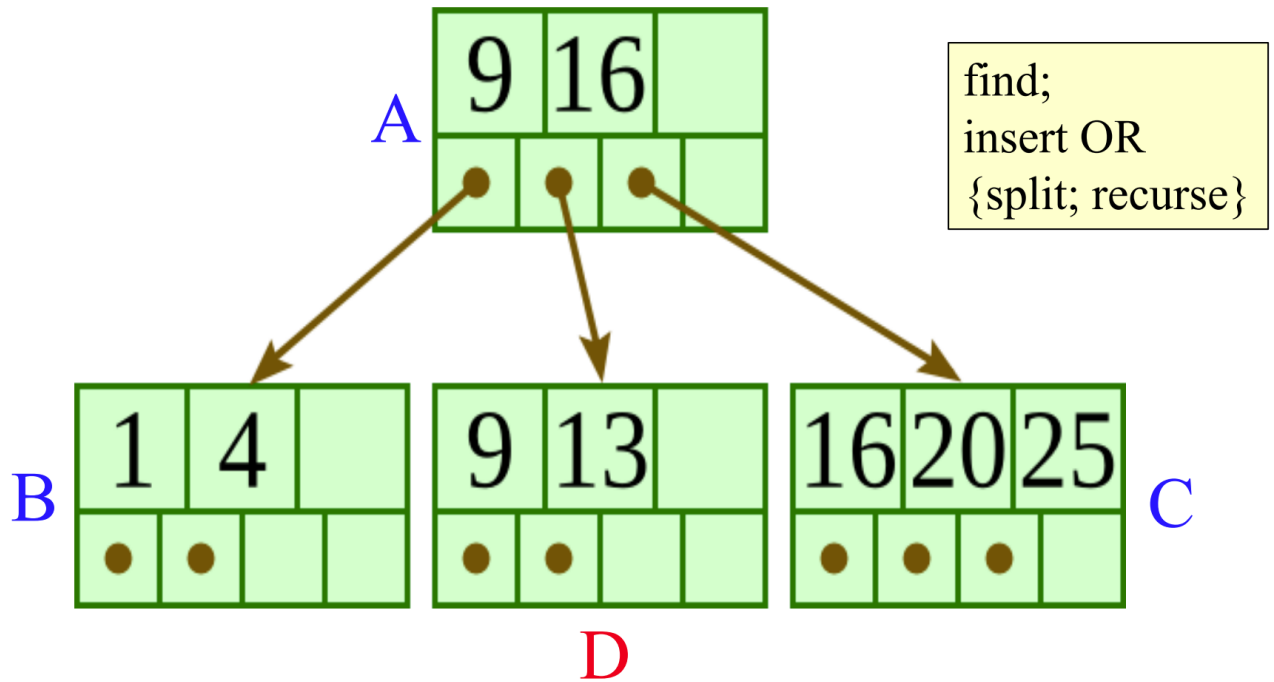


Cont’d …



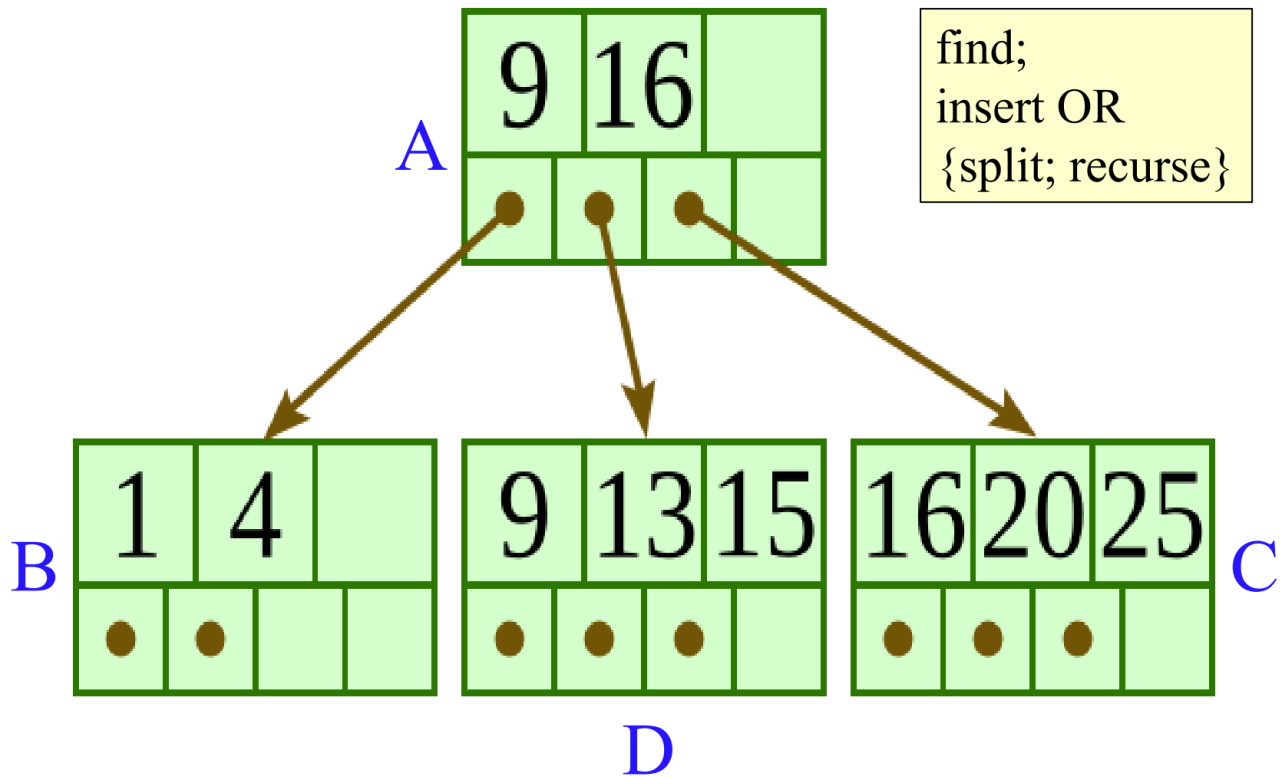
After inserting 13

Now insert 15

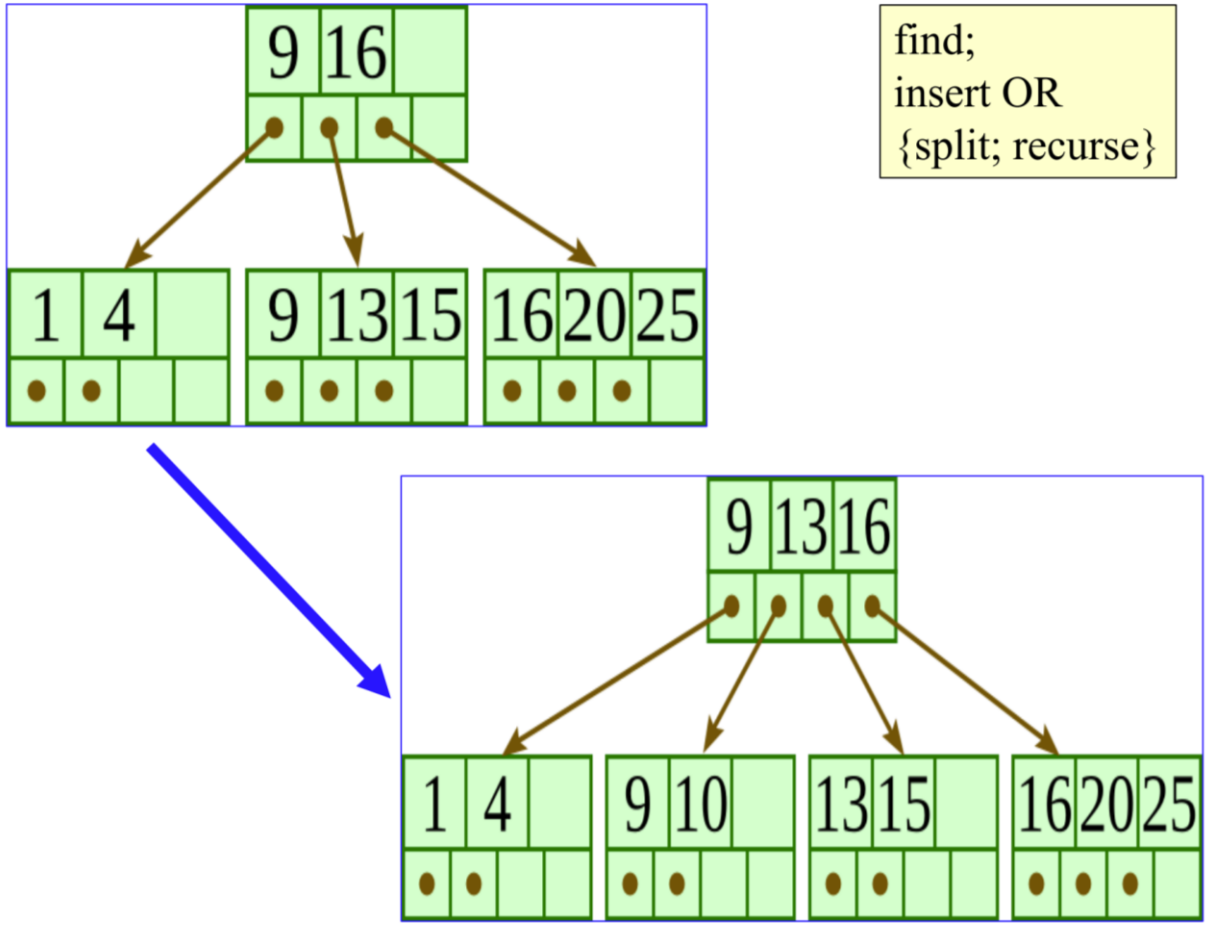


After inserting 15

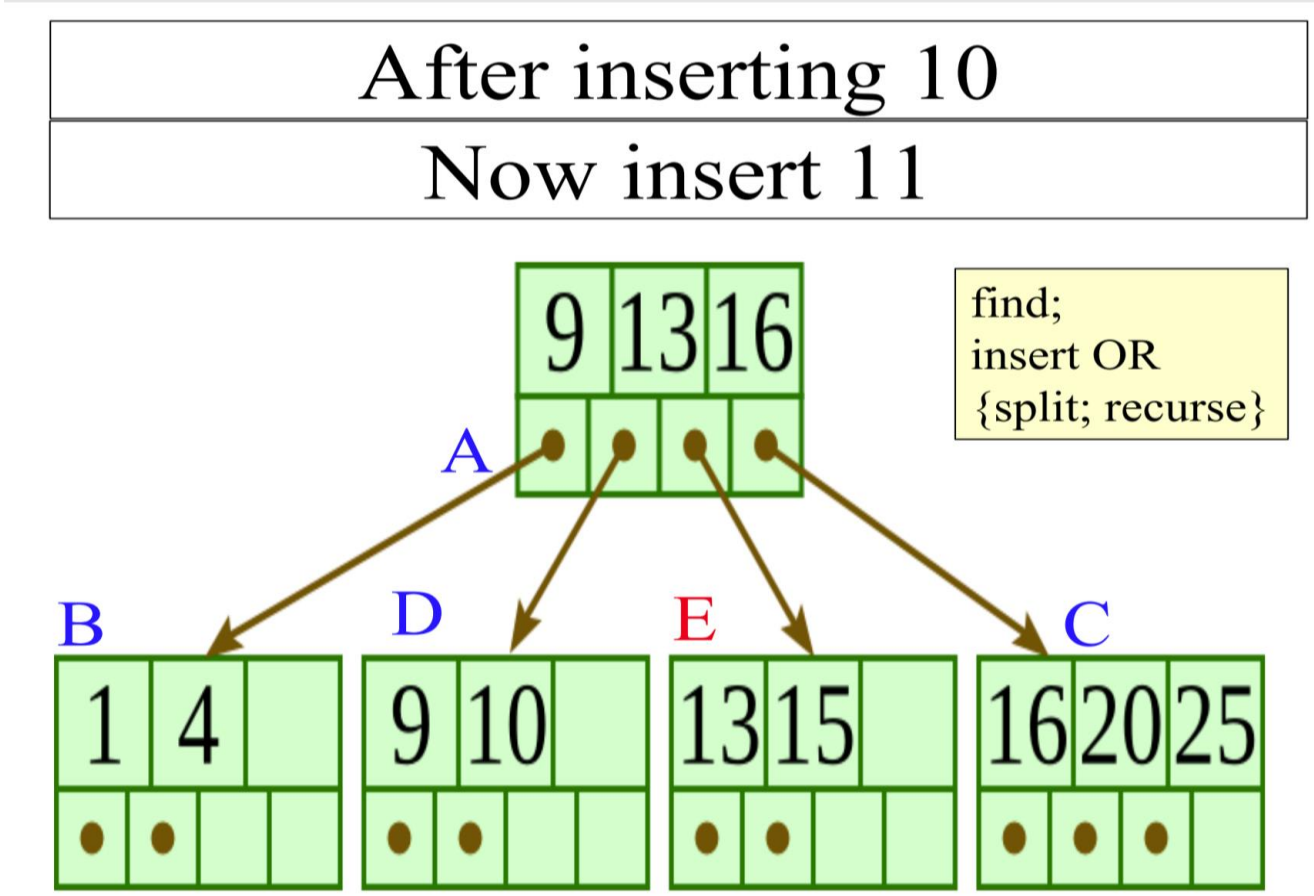
Now insert 10



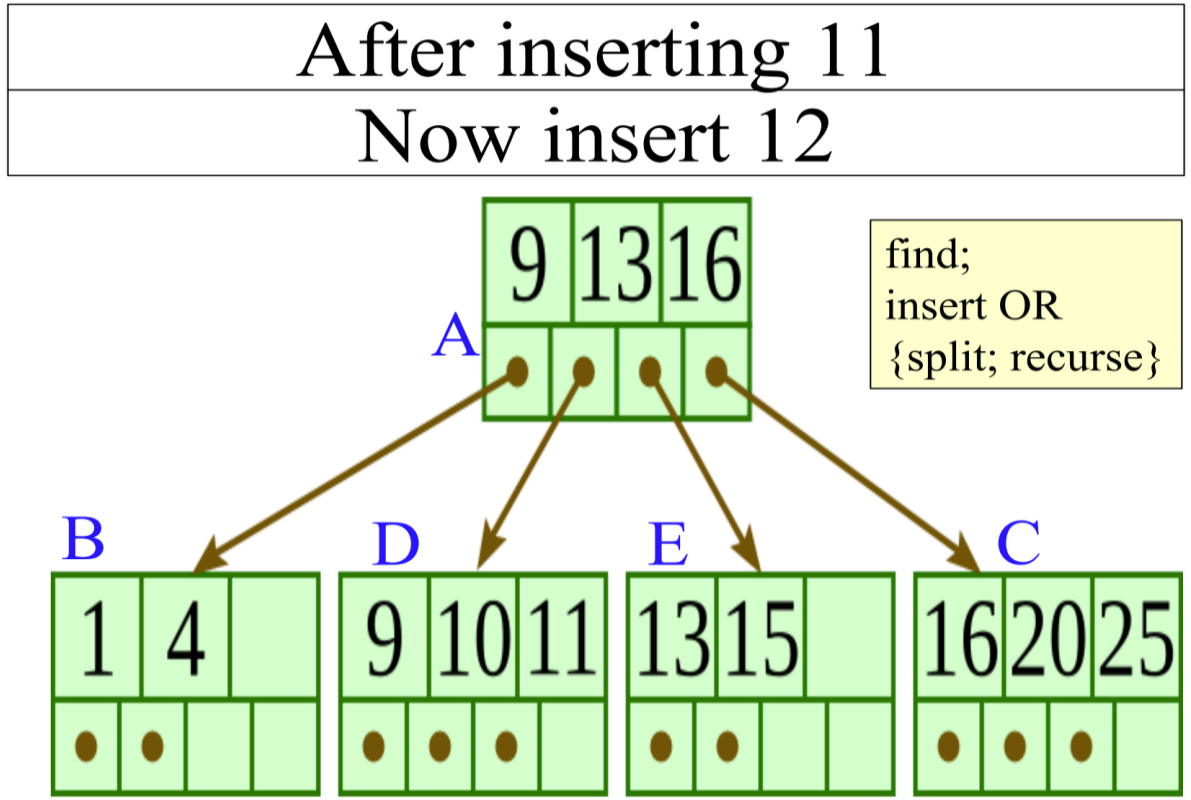
Cont’d …


9 16
1 4
9 13 15
16 20 25
find;
insert OR
{split; recurse}
9 13 16
1 4
9 10
13 15
16 20 25

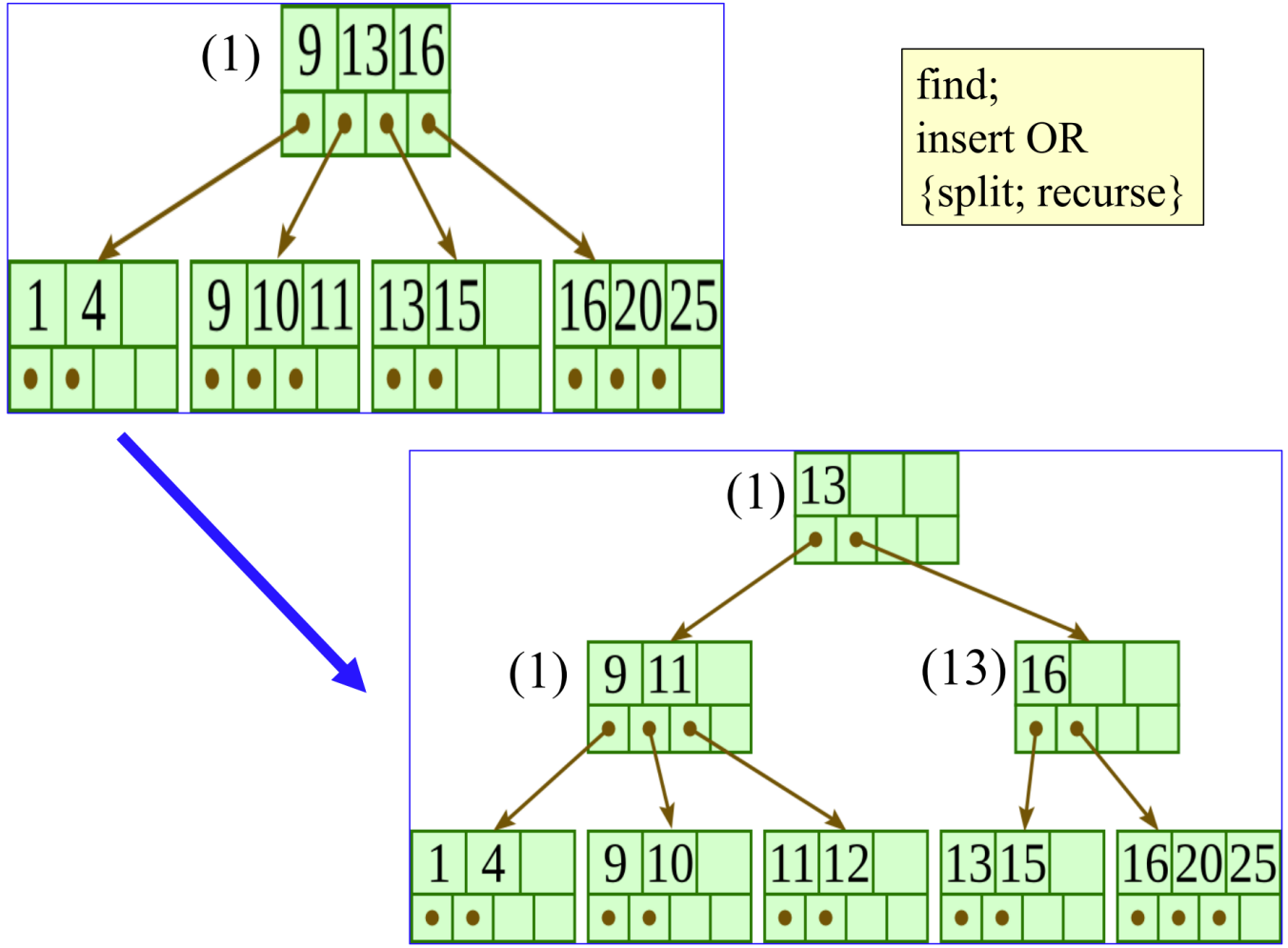
Cont’d …


After inserting 10
Now insert 11
9 13 16
A
find;
insert OR
{split; recurse}
B
1 4
D
9 10
E
13 15
C
16 20 25

Cont’d …

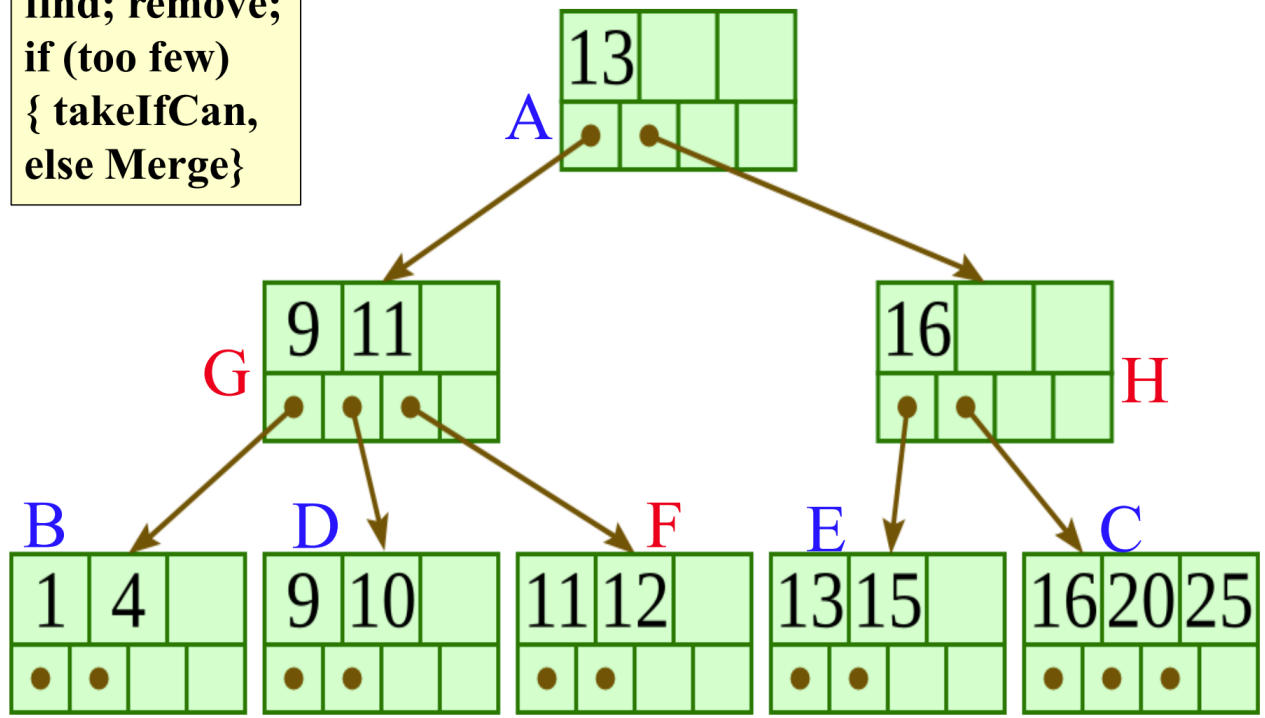

After inserting 11
Now insert 12
9 13 16
A
find;
insert OR
{split; recurse}
B
D
E
C
1 4
9 10 11
13 15
16 20 25

Cont’d …

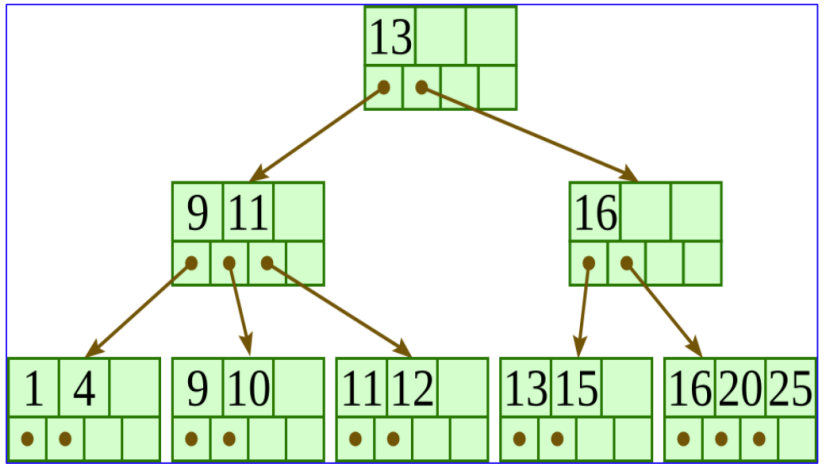

(1) 9 13 16
1 4
9 10 11
13 15
16 20 25
find;
insert OR
{split; recurse}
(1) 13
(1) 9 11
(13) 16
1 4
9 10
11 12
13 15
16 20 25

Now delete 13

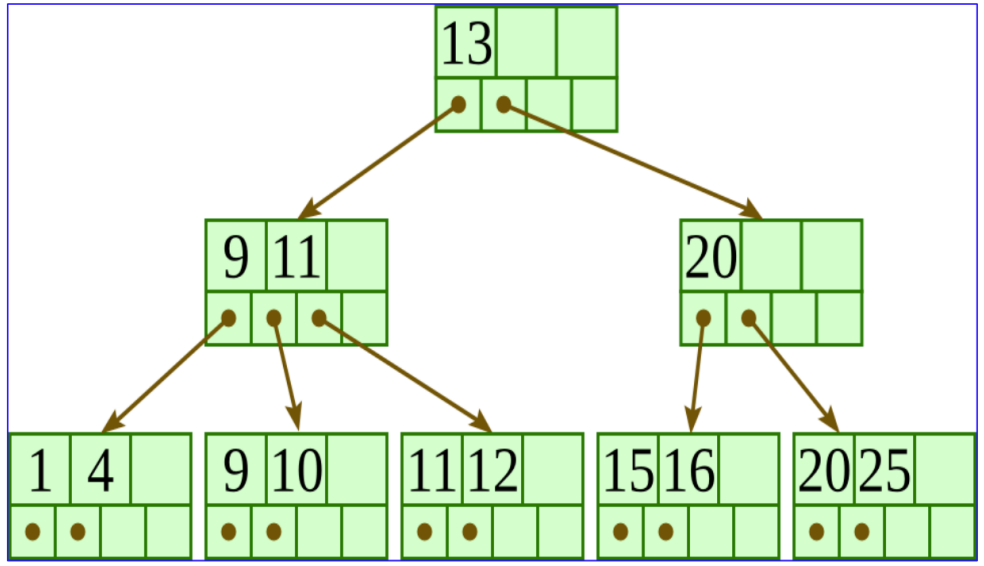
find; remove;
if (too few)
{ takeIfCan,
else Merge}



Cont’d …

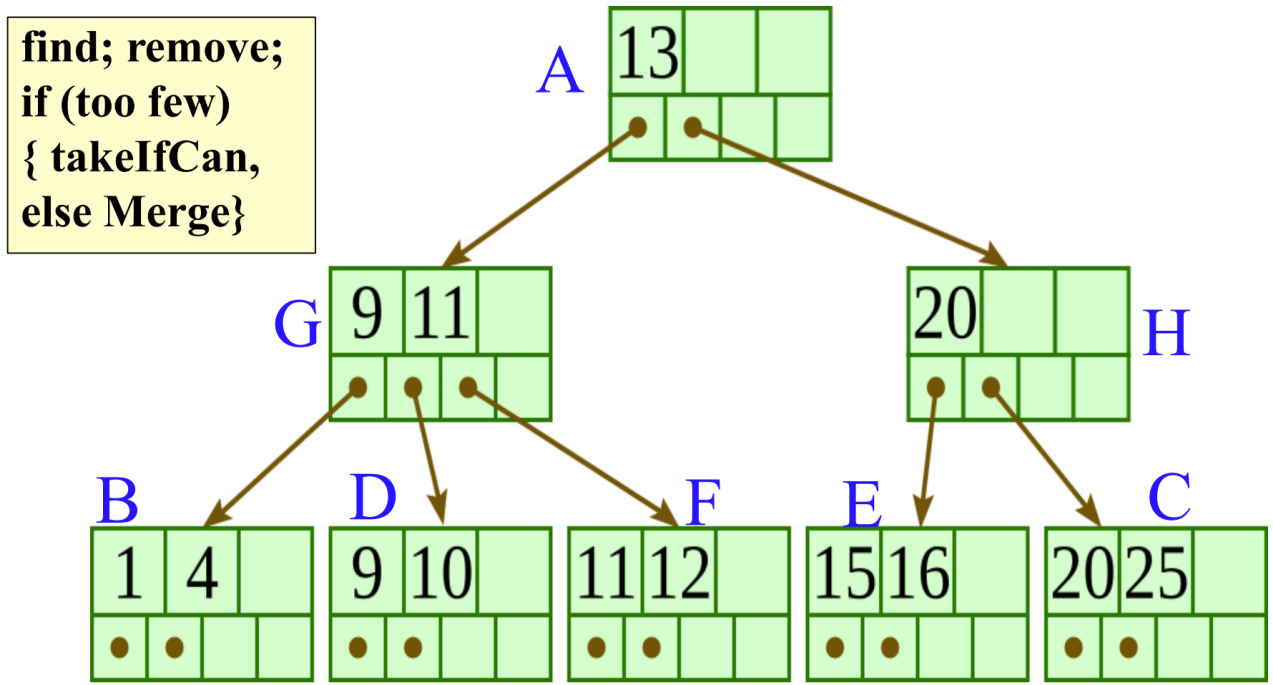


find; remove;
if (too few)
{ takeIfCan,
else Merge}

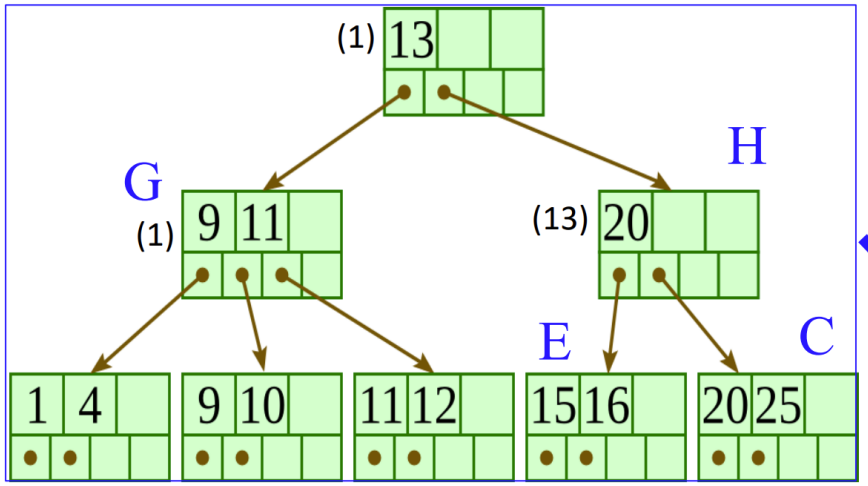


After deleting 13

Now delete 15



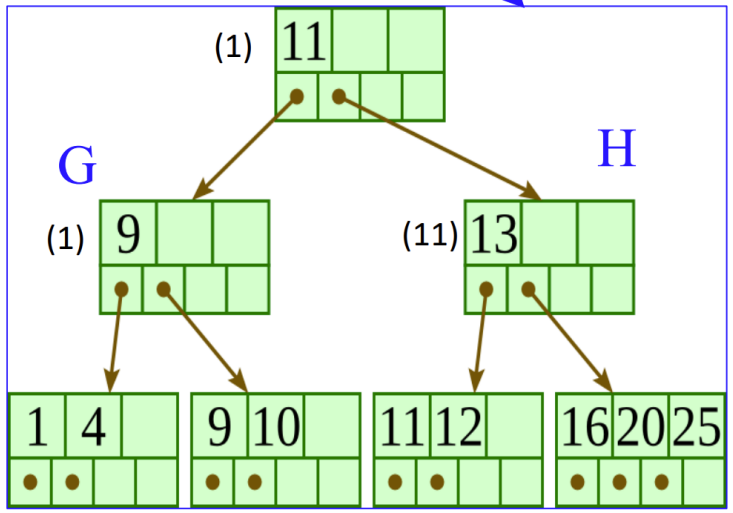
Cont'd …



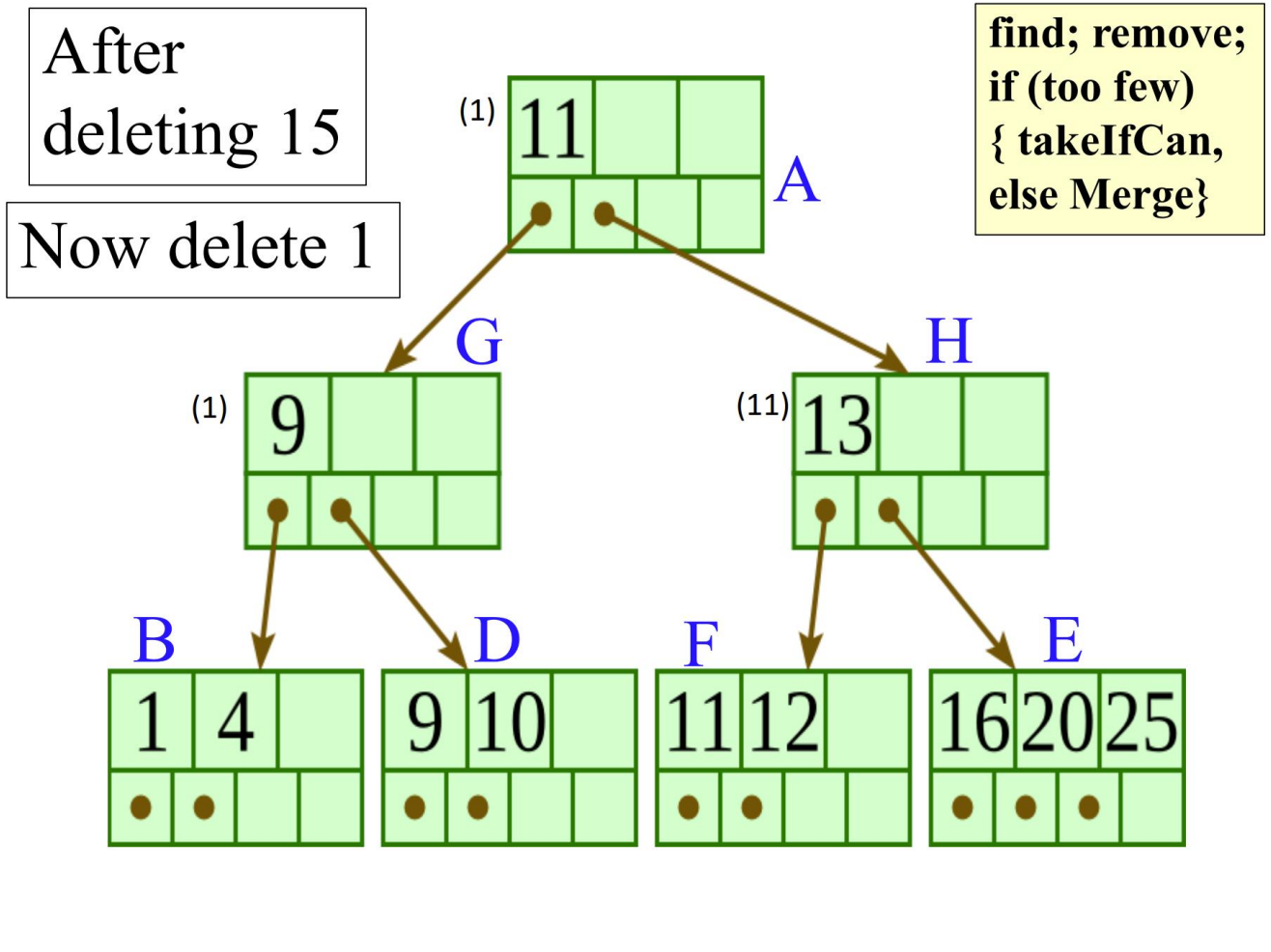
Smallest key value isn't stored in nonleaves, but is shown in brackets here.

13 is still in the root from before we deleted it – correct! all values in right subtree are >= 13 ☺

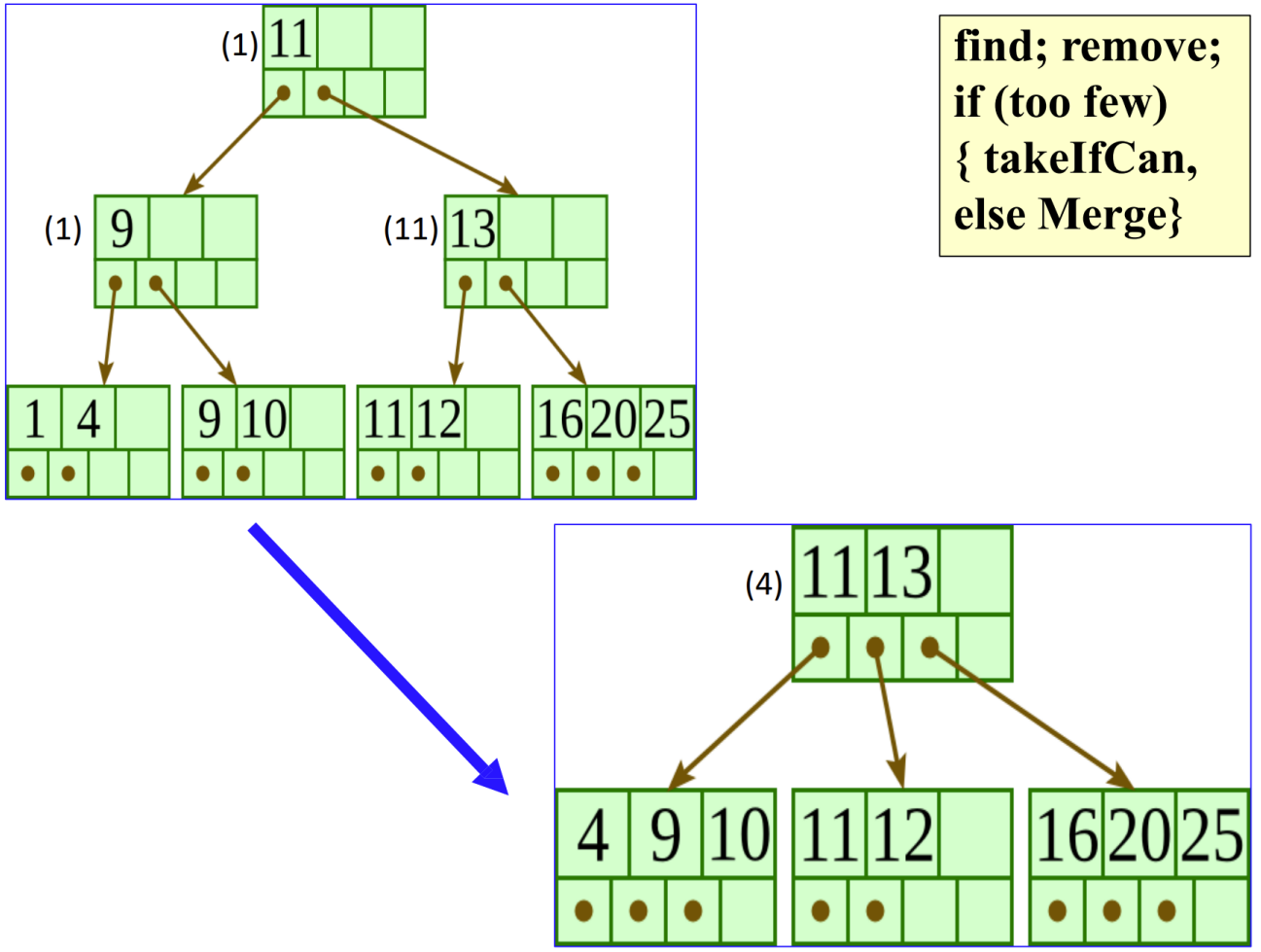
- **after drop 20 & merge E & C, H has < 2 children so we take the last one from its sibling G;**
- **G's keys are (1),9, 11, and H's remaining key is its first key (13) – actually algorithm gets key 13 from H's parent;**
- **thus halve 4 keys: (1),9,11,(13) so G gets(1),9 & H gets (11),13 (omit 11 as it is 1st key of H)**



Cont'd …


After deleting 15
Now delete 1
find; remove;
if (too few)
{ takeIfCan,
else Merge}
(1)
11
A
G
H
(1)
9
(11)
13
B
D
F
E
1 4
9 10
11 12
16 20 25

Cont’d …



find; remove;
if (too few)
{ takeIfCan,
else Merge}