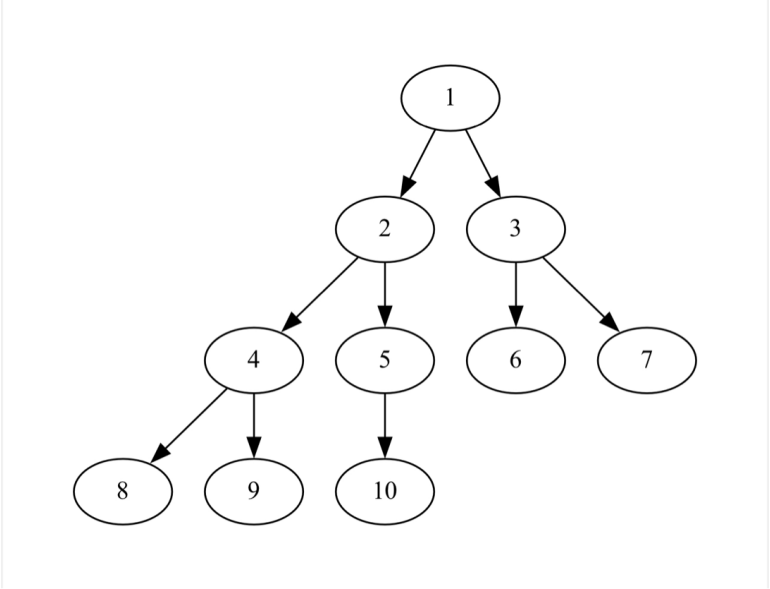
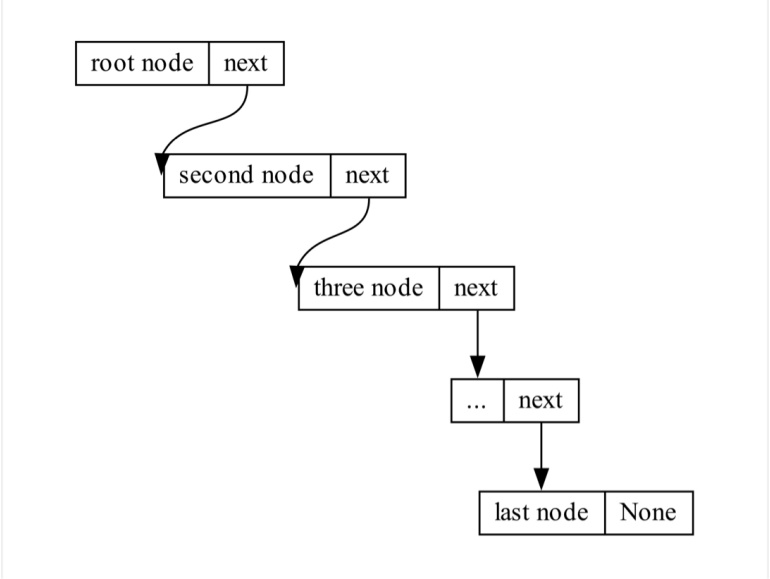
附加题答案：

```
from graphviz import Digraph

#优先级队列，小头堆

g = Digraph('G',filename='tree.gv')

g.attr('node',shap='circle')
g.node('node1',label='1')
g.node('node2',label='2')
g.node('node3',label='3')
g.node('node4',label='4')
g.node('node5',label='5')
g.node('node6',label='6')
g.node('node7',label='7')
g.node('node8',label='8')
g.node('node9',label='9')
g.node('node10',label='10')


g.edge('node1','node2')
g.edge('node1','node3')

g.edge('node2','node4')
g.edge('node2','node5')

g.edge('node3','node6')
g.edge('node3','node7')

g.edge('node4','node8')
g.edge('node4','node9')

g.edge('node5','node10')



print(g)

#g.render(directory=r"e:", filename = "ff4.gv", format = "pdf", view = True)
g .view()
```




```
from graphviz import Digraph, nohtml

g = Digraph('g', filename='sllt.gv',
node_attr={'shape': 'record', 'height': '.1'})

g.node('node1', nohtml('<f1> second node|<f2> next'))
g.node('node2', nohtml('<f1> three node|<f2> next'))
g.node('node3', nohtml('<f1> ...|<f2>  next'))
g.node('node4', nohtml('<f1> last node|<f2> None'))
g.edge('node0:f2', 'node1:f1')
g.edge('node1:f2', 'node2:f1')
g.edge('node2:f2', 'node3:f1')
g.edge('node3:f2', 'node4:f1')


g.view()
```

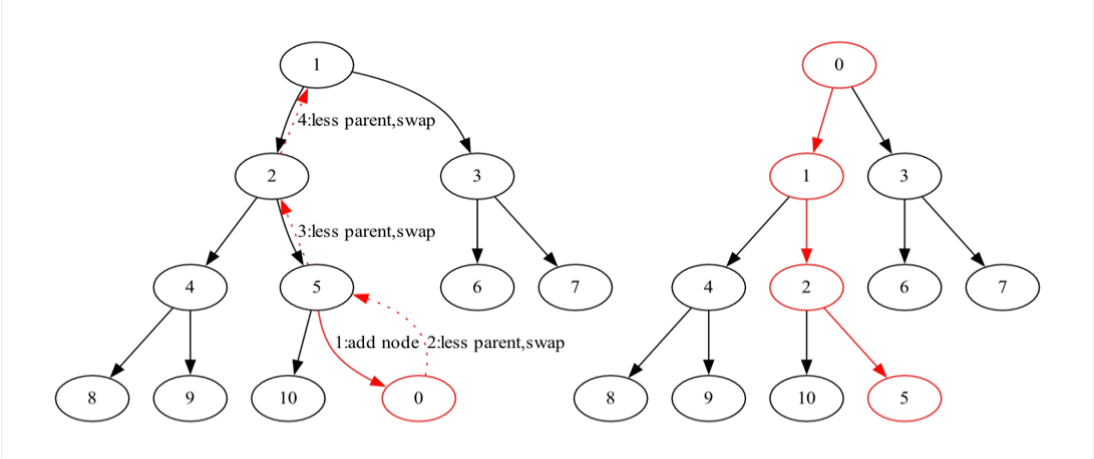



```
from graphviz import Digraph
```

#小头堆,插入实现过程

```
g = Digraph('G',filename='minPQ_insert.gv')

g.attr('node',shap='circle')

with g.subgraph(name='add_process') as c:
    c.attr(style='filled', color='lightgrey')
    c.attr(label='add new node')


    c.node('node1',label='1')
    c.node('node2',label='2')
    c.node('node3',label='3')
    c.node('node4',label='4')
    c.node('node5',label='5')
    c.node('node6',label='6')
    c.node('node7',label='7')
    c.node('node8',label='8')
    c.node('node9',label='9')
    c.node('node10',label='10')
    c.node('node11',label='0', color = 'red')


    c.edge('node1','node2')
    c.edge('node1','node3')

    c.edge('node2','node4')
    c.edge('node2','node5')

    c.edge('node3','node6')
    c.edge('node3','node7')

    c.edge('node4','node8')
    c.edge('node4','node9')

    c.edge('node5','node10')
    c.edge('node5','node11',color='red',label='1:add node')

    c.edge('node11','node5',color='red',style='dotted',label='2:less
parent,swap')
    c.edge('node5','node2',color='red',style='dotted',label='3:less
parent,swap')
    c.edge('node2','node1',color='red',style='dotted',label='4:less
parent,swap')



with g.subgraph(name='add_complete') as d:
    d.attr(style='filled', color='blue')



    d.node('node21',label='0', color = 'red')
    d.node('node22',label='1', color = 'red')
    d.node('node23',label='3')
    d.node('node24',label='4')
```

```
    d.node('node25',label='2', color = 'red')
    d.node('node26',label='6')
    d.node('node27',label='7')
    d.node('node28',label='8')
    d.node('node29',label='9')
    d.node('node30',label='10')
    d.node('node31',label='5', color = 'red')


    d.edge('node21','node22', color = 'red')
    d.edge('node21','node23')

    d.edge('node22','node24')
    d.edge('node22','node25', color = 'red')

    d.edge('node23','node26')
    d.edge('node23','node27')

    d.edge('node24','node28')
    d.edge('node24','node29')

    d.edge('node25','node30')
    d.edge('node25','node31',color='red')

    d.attr(label='add new node complete')


#g.render(directory=r"e:", filename = "ff4.gv", format = "pdf", view = True)
g.view()
```




```
from graphviz import Digraph

#小头堆,删除实现过程

g = Digraph('G',filename='minPQ_delMin.gv')

g.attr('node',shap='circle')

with g.subgraph(name='del_process') as c:
    c.attr(style='filled', color='lightgrey')
    c.attr(label='del node')
```

```
    c.node('node1',label='1')
    c.node('node2',label='2')
    c.node('node3',label='3')
    c.node('node4',label='4')
    c.node('node5',label='5')
    c.node('node6',label='6')
    c.node('node7',label='7')
    c.node('node8',label='8')
    c.node('node9',label='9')
    c.node('node10',label='10', color = 'red')


    c.edge('node1','node2')
    c.edge('node1','node3')

    c.edge('node2','node4')
    c.edge('node2','node5')

    c.edge('node3','node6')
    c.edge('node3','node7')

    c.edge('node4','node8')
    c.edge('node4','node9')

    c.edge('node5','node10')
    c.edge('node10','node1', color='red',style='dashed',label='1.del
root ,last node move to root')
    c.edge('node1','node2', color='red',style='dashed',label='2.large
child,swap')
    c.edge('node2','node4', color='red',style='dashed',label='3.large
child,swap')
    c.edge('node4','node8', color='red',style='dashed',label='4.large
child,swap')



with g.subgraph(name='add_complete') as d:
    d.attr(style='filled', color='blue')



    d.node('node21',label='2', color = 'red')
    d.node('node22',label='4', color = 'red')
    d.node('node23',label='3')
    d.node('node24',label='8', color = 'red')
    d.node('node25',label='5')
    d.node('node26',label='6')
    d.node('node27',label='7')
    d.node('node28',label='10', color = 'red')
    d.node('node29',label='9')



    d.edge('node21','node22', color = 'red')
    d.edge('node21','node23')
```

```
    d.edge('node22','node24', color = 'red')
    d.edge('node22','node25')

    d.edge('node23','node26')
    d.edge('node23','node27')

    d.edge('node24','node28',color='red')
    d.edge('node24','node29')


    d.attr(label='del node complete')


#g.render(directory=r"e:", filename = "ff4.gv", format = "pdf", view = True)
g.view()
```