McCreight's Suffix Tree Algorithm

```
Construct tree for x[1..n]
for i = 1 to n do
        if head(i)=$\epsilon$ then
                head(i+1) = slowscan($\epsilon$,s(tail(i)))
                add i+1 and head(i+1) as node if necessary
                continue
        u = parent(head(i)) ; v = label(u,head(i))
        if u$\neq\epsilon$ then w = fastscan(s(u),v)
        else            w = fastscan($\epsilon$,v[2..|v|])
        if w is an edge then
                add a node for w
                head(i+1) = w
        else if w is a node then
                head(i+1) = slowscan(w,tail(i))
                add head(i+1) as node if necessary
        s(head(i)) = w
        add leaf i+1 and edge between head(i+1) and i+1
```

Special Case

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
    if head($i$)=$\epsilon$ then
        head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
        add $i$+1 and head($i$+1) as node if necessary
        continue
    $u$ = parent(head($i$)) ; $v$ = label($u$,head
    if $u \neq \epsilon$ then $w$ = fastscan($s(u)$,$v$)
    else             $w$ = fastscan($\epsilon$,$v[2..|v|]$)
    if $w$ is an edge then
        add a node for $w$
        head($i$+1) = $w$
    else if $w$ is a node then
        head($i$+1) = slowscan($w$,tail($i$))
        add head($i$+1) as node if necessary
    $s$(head($i$)) = $w$
    add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

Special Case:
When head(*i*) is empty there is no information to exploit

Short Cut in Search

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
    if head($i$)=$\epsilon$ then
        head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
        add $i$+1 and head($i$+1) as node if necessary
        continue
    $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
    if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
    else              $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
    if $w$ is an edge then
        add a node for $w$
        head($i$+1) = $w$
    else if $w$ is a node then
        head($i$+1) = slowsca
        add head($i$+1) as no
    $s$(head($i$)) = $w$
    add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

Use **suffix link** and **fastscan** to quickly find *w*, the overlap between *s*(head(*i*)) and head(*i*+1)

Add inner nodes

```
Construct tree for $\mathbf{x}[1..n]$
for $i$ = 1 to $n$ do
        if head($i$)=$\epsilon$ then
                head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
                add $i$+1 and head($i$+1) as node if necessary
                continue
        $u$ = parent(head($i$)) ; $v$ = label($u$
        if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
        else            $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
        if $w$ is an edge then
                add a node for $w$
                head($i$+1) = $w$
        else if $w$ is a node then
                head($i$+1) = slowscan($w$,tail($i$))
                add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

Add *w* and head(*i*+1) as needed

Update Suffix-Link

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
    if head($i$)=$\epsilon$ then
        head($i$+1) = slowscan($\epsilon$,$s$(tail($i$)))
        add $i$+1 and head($i$+1) a
        continue
    $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
    if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
    else          $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
    if $w$ is an edge then
        add a node for $w$
        head($i$+1) = $w$
    else if $w$ is a node then
        head($i$+1) = slowscan($w$,tail($i$))
        add head($i$+1) as node if necessary
    $s$(head($i$)) = $w$
    add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

make the suffix link of head(*i*) point to *w*

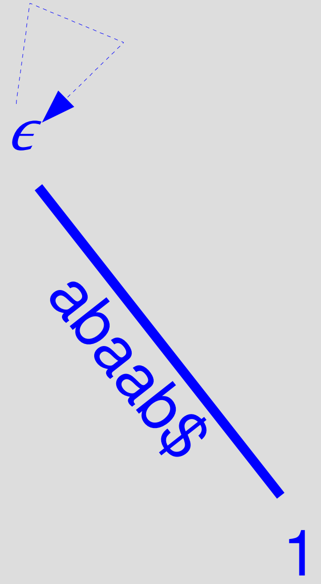
Add leaf for suffix x[*i*..*n*]

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
        if head($i$)=$\epsilon$ then
                head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
                add $i$+1 and head($i$+1) as node if necessary
                continue
        $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
        if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
        else          $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
        if $w$ is an edge then
                add a node for $w$
                head($i$+1) = $w$
        else if $w$ is a node then
                head($i$+1) = slowscan($w$,tail($i$))
                add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

Add leaf for **x**[*i*..*n*]

Example: x = *abaab*

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
        if head($i$)=$\epsilon$ then
            head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
            add $i$+1 and head($i$+1) as node if necessary
            continue
        $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
        if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
        else           $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
        if $w$ is an edge then
            add a node for $w$
            head($i$+1) = $w$
        else if $w$ is a node then
            head($i$+1) = slowscan($w$,tail($i$))
            add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

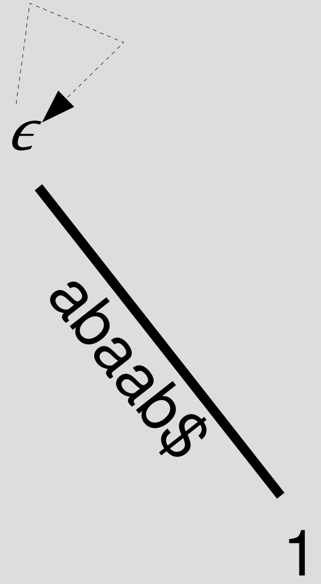


Example: x = *abaab*, *i*=1, inserting baab$

```
Construct tree for x[1..n]
for i = 1 to n do
        if head(i)=ε then
                head(i+1) = slowscan(ε,s(tail(i)))
                add i+1 and head(i+1) as node if necessary
                continue
        u = parent(head(i)) ; v = label(u,head(i))
        if u≠ε then w = fastscan(s(u),v)
        else        w = fastscan(ε,v[2..|v|])
        if w is an edge then
                add a node for w
                head(i+1) = w
        else if w is a node then
                head(i+1) = slowscan(w,tail(i))
                add head(i+1) as node if necessary
        s(head(i)) = w
        add leaf i+1 and edge between head(i+1) and i+1
```

head(1)=ϵ

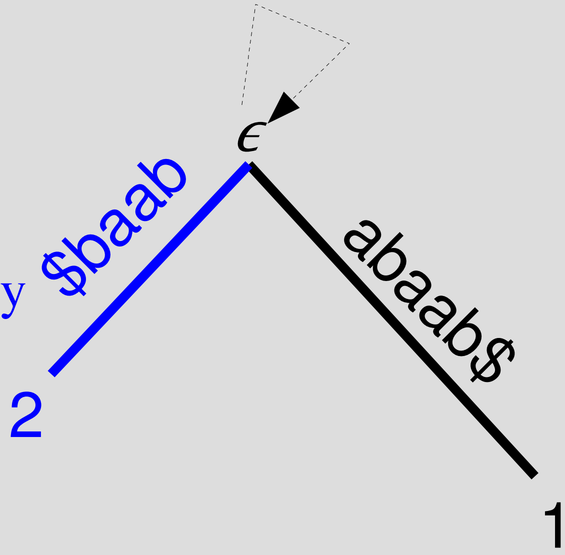
tail(1)=abaab$



Example: x = *abaab*, *i*=1, inserting baab$

```
Construct tree for x[1..$n$]
for $i$ = 1 to $n$ do
        if head($i$)=$\epsilon$ then
                head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
                add $i$+1 and head($i$+1) as node if necessary
                continue
        $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
        if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
        else              $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
        if $w$ is an edge then
                add a node for $w$
                head($i$+1) = $w$
        else if $w$ is a node then
                head($i$+1) = slowscan($w$,tail($i$))
                add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

head(2)=ϵ
tail(2)=baab$

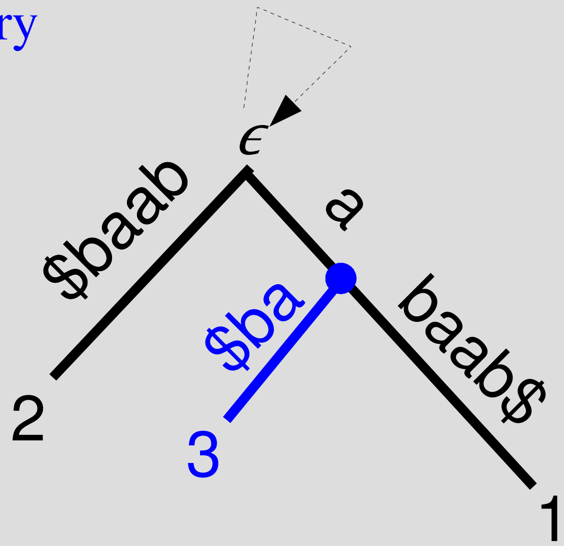


Example: x = *abaab*, *i*=2, inserting aab$

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
    if head($i$)=$\epsilon$ then
        head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
        add $i$+1 and head($i$+1) as node if necessary
        continue
    $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
    if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
    else          $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
    if $w$ is an edge then
        add a node for $w$
        head($i$+1) = $w$
    else if $w$ is a node then
        head($i$+1) = slowscan($w$,tail($i$))
        add head($i$+1) as node if necessary
    $s$(head($i$)) = $w$
    add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

head(2)=ϵ
tail(2)=baab$

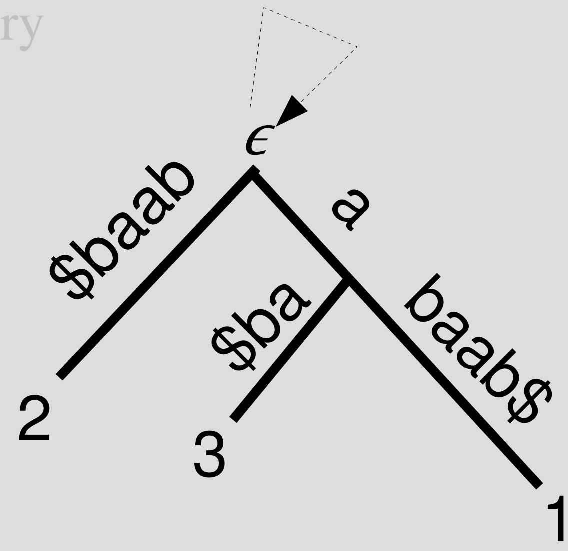
head(3)=a
tail(3)=ab$



Example: x = *abaab, i*=3, inserting ab$

```
Construct tree for $\mathbf{x}[1..n]$
for $i$ = 1 to $n$ do
        if head($i$)=$\epsilon$ then
                head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
                add $i$+1 and head($i$+1) as node if necessary
                continue
        $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
        if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
        else              $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
        if $w$ is an edge then
                add a node for $w$
                head($i$+1) = $w$
        else if $w$ is a node then
                head($i$+1) = slowscan($w$,tail($i$))
                add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

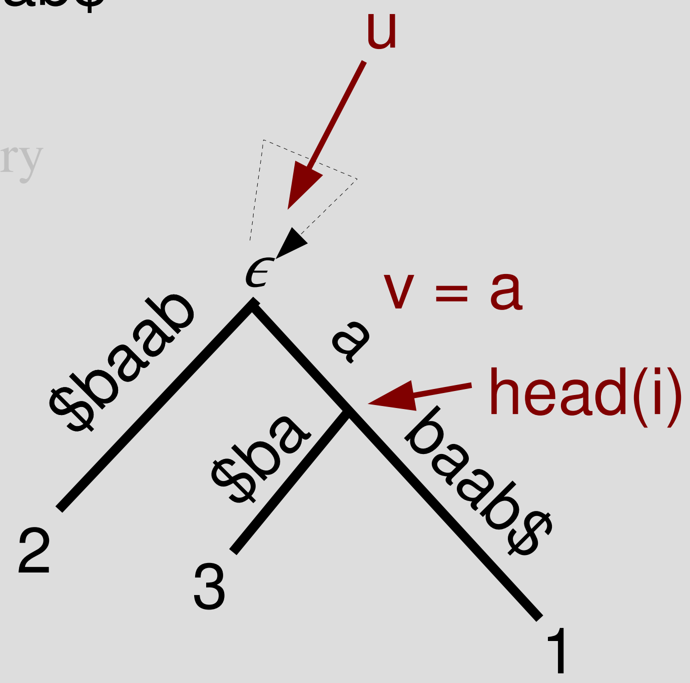
head(3)=a
tail(3)=ab$



Example: x = *abaab, i*=3, inserting ab$

```
Construct tree for x[1..n]
for i = 1 to n do
        if head(i)=ε then
                head(i+1) = slowscan(ε,s(tail(i)))
                add i+1 and head(i+1) as node if necessary
                continue
        u = parent(head(i)) ; v = label(u,head(i))
        if u≠ε then w = fastscan(s(u),v)
        else            w = fastscan(ε,v[2..|v|])
        if w is an edge then
                add a node for w
                head(i+1) = w
        else if w is a node then
                head(i+1) = slowscan(w,tail(i))
                add head(i+1) as node if necessary
        s(head(i)) = w
        add leaf i+1 and edge between head(i+1) and i+1
```

head(3)=a
tail(3)=ab$



Example: x = *abaab*, *i*=3, inserting ab$

head(3)=a
tail(3)=ab$

```
Construct tree for x[1..n]
for i = 1 to n do
        if head(i)=$\epsilon$ then
                head(i+1) = slowscan($\epsilon$,s(tail(i)))
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                add a node for w
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        else if w is a node then
                head(i+1) = slowscan(w,tail(i))
                add head(i+1) as node if necessary
        s(head(i)) = w
        add leaf i+1 and edge between head(i+1) and i+1
```
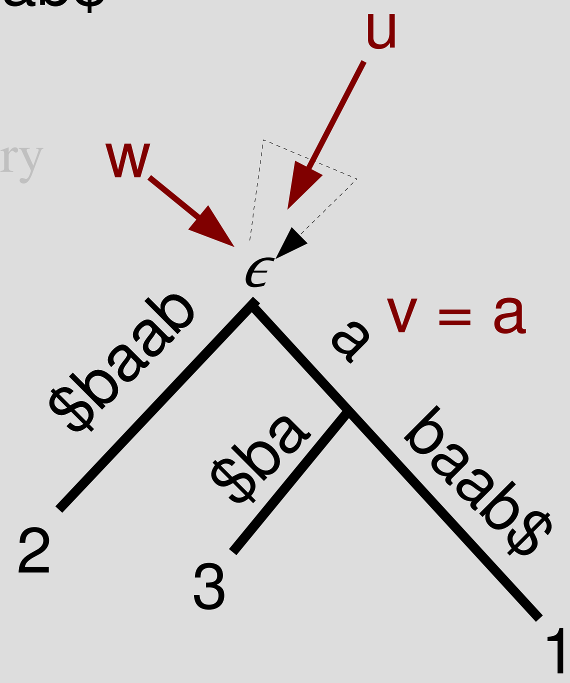
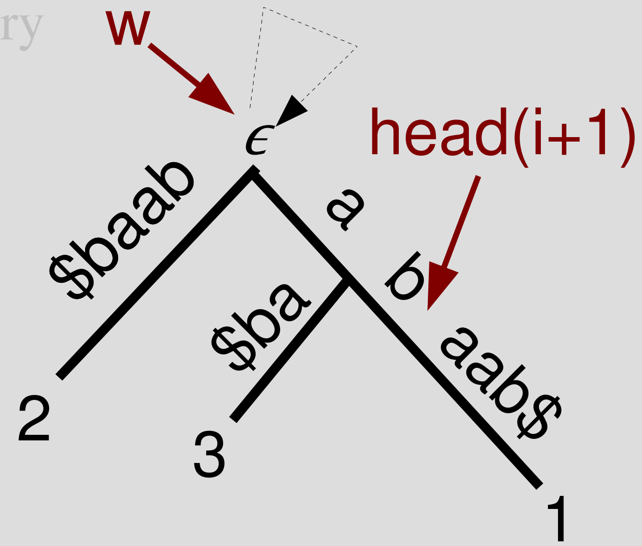

v[2..1] = ϵ



Example: x = *abaab*, *i*=3, inserting ab$

head(3)=a
tail(3)=ab$

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
        if head($i$)=$\epsilon$ then
                head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
                add $i$+1 and head($i$+1) as node if necessary
                continue
        $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
        if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
        else              $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
        if $w$ is an edge then
                add a node for $w$
                head($i$+1) = $w$
        else if $w$ is a node then
                head($i$+1) = slowscan($w$,tail($i$))
                add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```



Example: x = *abaab*, *i*=3, inserting ab$

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
        if head($i$)=$\epsilon$ then
                head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
                add $i$+1 and head($i$+1) as node if necessary
                continue
        $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
        if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
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                head($i$+1) = slowscan($w$,tail($i$))
                add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```
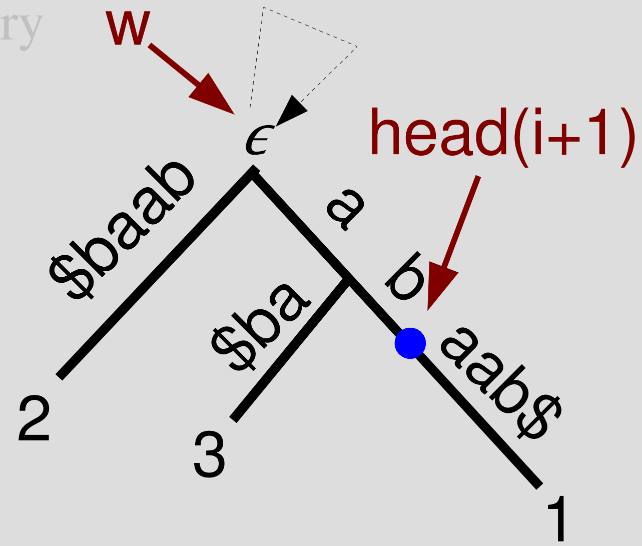
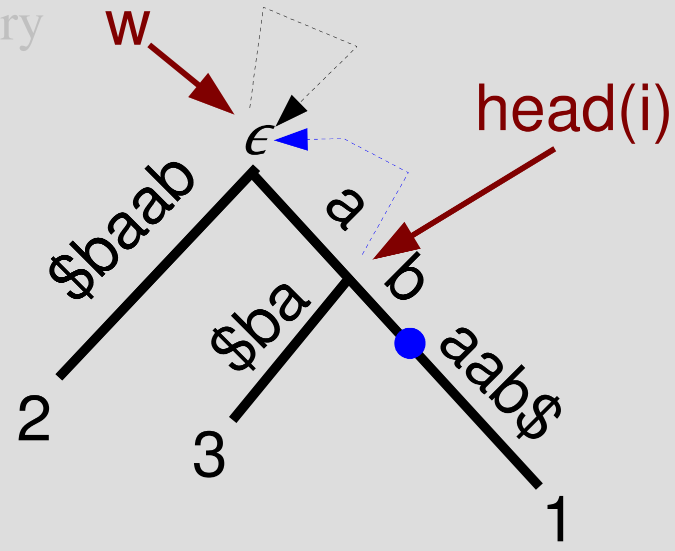

head(3)=a
tail(3)=ab$



Example: x = *abaab*, *i*=3, inserting ab$

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
        if head($i$)=$\epsilon$ then
                head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
                add $i$+1 and head($i$+1) as node if necessary
                continue
        $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
        if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
        else            $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
        if $w$ is an edge then
                add a node for $w$
                head($i$+1) = $w$
        else if $w$ is a node then
                head($i$+1) = slowscan($w$,tail($i$))
                add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

head(3)=a
tail(3)=ab$



Example: x = *abaab*, *i*=3, inserting ab$

```
Construct tree for x[1..n]
for $i$ = 1 to $n$ do
    if head($i$)=$\epsilon$ then
        head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
        add $i$+1 and head($i$+1) as node if necessary
        continue
    $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
    if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
    else              $w$ = fastscan($\epsilon$,$v$[2..|v|])
    if $w$ is an edge then
        add a node for $w$
        head($i$+1) = $w$
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        head($i$+1) = slowscan($w$,tail($i$))
        add head($i$+1) as node if necessary
    $s$(head($i$)) = $w$
    add leaf $i$+1 and edge between head($i$+1) and $i$+1
```
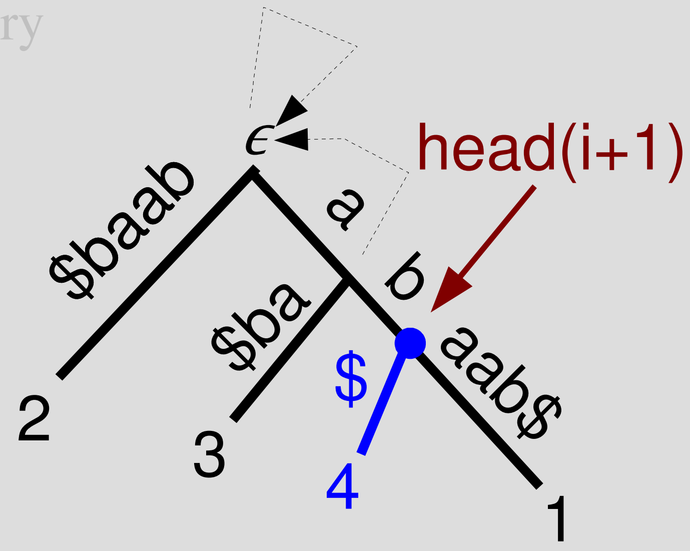
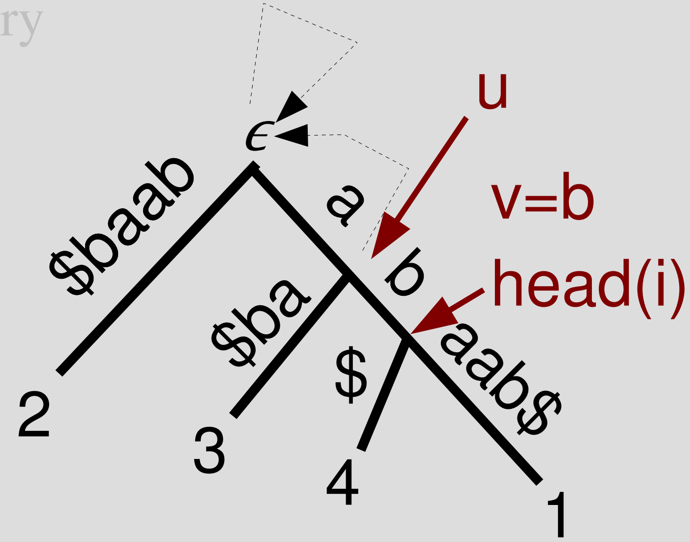

head(3)=a
tail(3)=ab$



Example: x = *abaab*, *i*=4, inserting b$

```
Construct tree for x[1..n]
for $i$ = 1 to $n$ do
        if head($i$)=$\epsilon$ then
                head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
                add $i$+1 and head($i$+1) as node if necessary
                continue
        $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
        if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
        else            $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
        if $w$ is an edge then
                add a node for $w$
                head($i$+1) = $w$
        else if $w$ is a node then
                head($i$+1) = slowscan($w$,tail($i$))
                add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

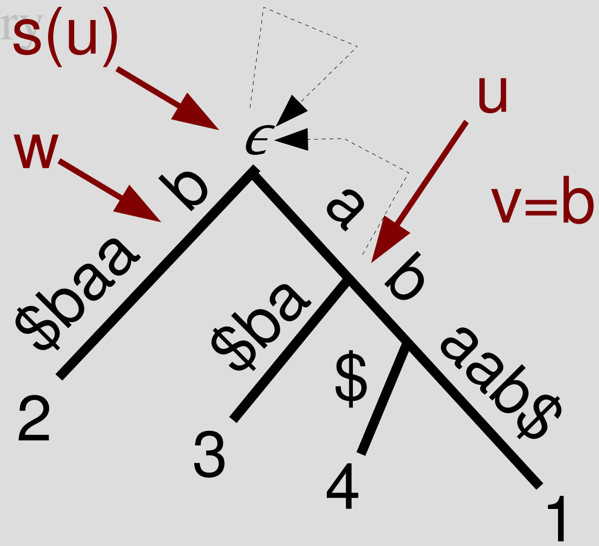
head(4)=ab
tail(4)=$



Example: x = *abaab*, *i*=4, inserting b$

```
Construct tree for x[1..$n$]
for $i$ = 1 to $n$ do
        if head($i$)=$\epsilon$ then
                head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
                add $i$+1 and head($i$+1) as node if necessary
                continue
        $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
        if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
        else            $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
        if $w$ is an edge then
                add a node for $w$
                head($i$+1) = $w$
        else if $w$ is a node then
                head($i$+1) = slowscan($w$,tail($i$))
                add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

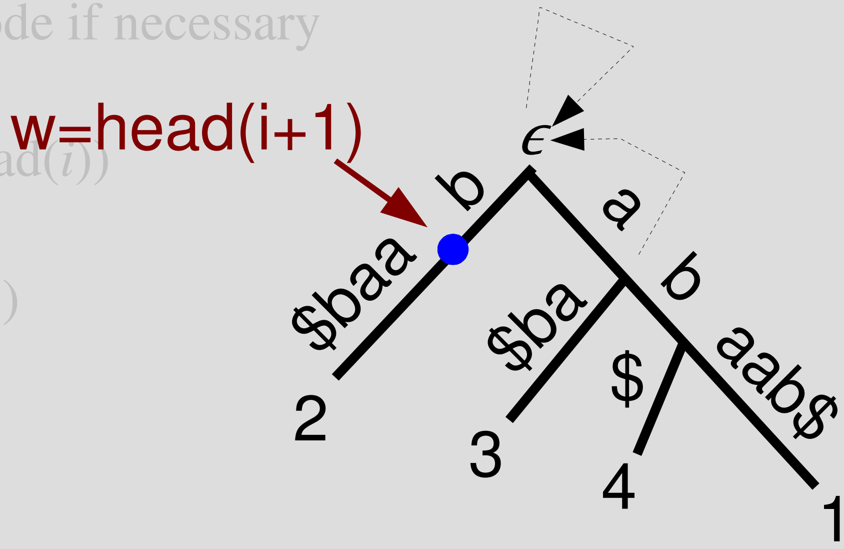
head(4)=ab
tail(4)=$



Example: x = *abaab*, *i*=4, inserting b$

```
Construct tree for x[1..n]
for i = 1 to n do
        if head(i)=ε then
                head(i+1) = slowscan(ε,s(tail(i)))
                add i+1 and head(i+1) as node if necessary
                continue
        u = parent(head(i)) ; v = label(u,head(i))
        if u≠ε then w = fastscan(s(u),v)
        else            w = fastscan(ε,v[2..|v|])
        if w is an edge then
                add a node for w
                head(i+1) = w
        else if w is a node then
                head(i+1) = slowscan(w,tail(i))
                add head(i+1) as node if necessary
        s(head(i)) = w
        add leaf i+1 and edge between head(i+1) and i+1
```

head(4)=ab
tail(4)=$



Example: x = *abaab*, *i*=4, inserting b$

```
Construct tree for x[1..n]
for i = 1 to n do
        if head(i)=ε then
                head(i+1) = slowscan(ε,s(tail(i)))
                add i+1 and head(i+1) as node if necessary
                continue
        u = parent(head(i)) ; v = label(u,head(i))
        if u≠ε then w = fastscan(s(u),v)
        else            w = fastscan(ε,v[2..|v|])
        if w is an edge then
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                head(i+1) = slowscan(w,tail(i))
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        s(head(i)) = w
        add leaf i+1 and edge between head(i+1) and i+1
```
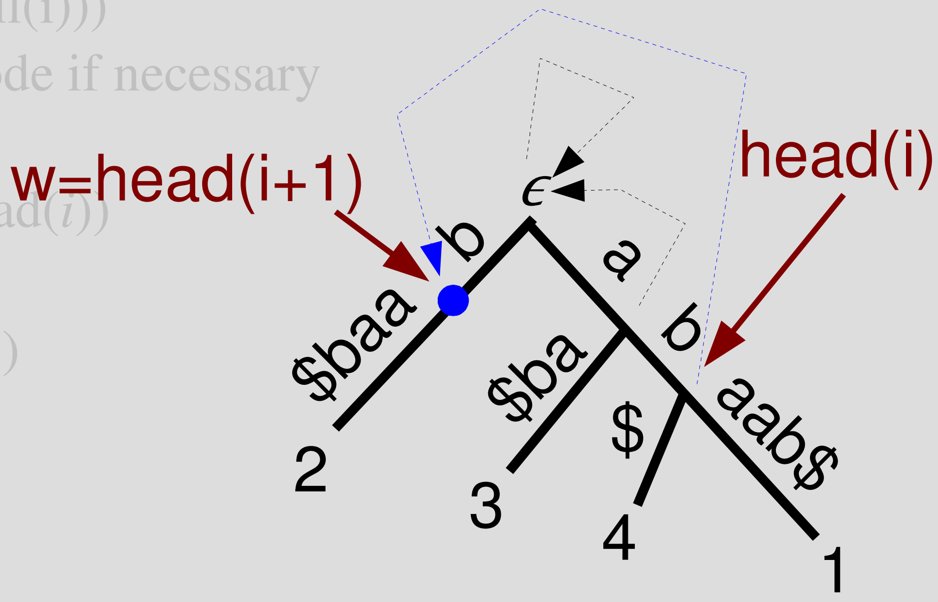
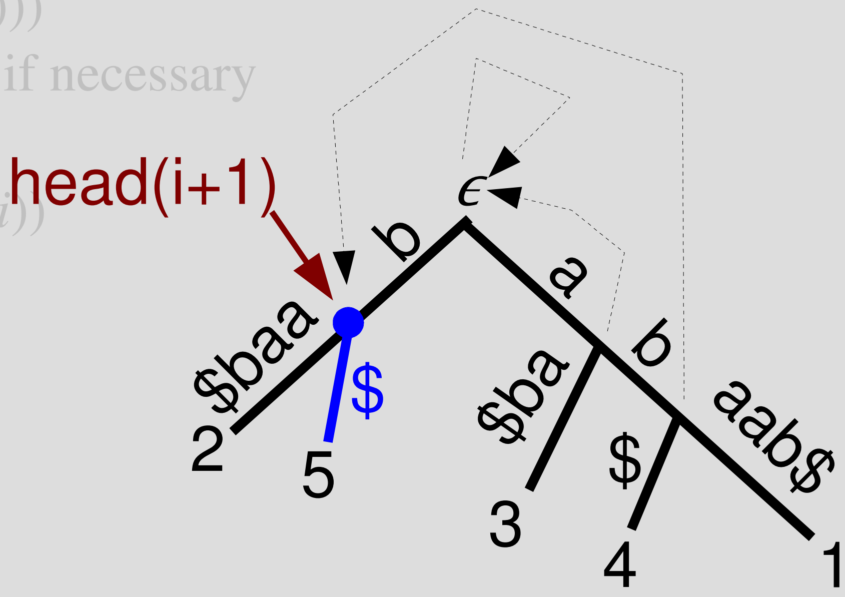

head(4)=ab
tail(4)=$



Example: x = *abaab*, *i*=4, inserting b$

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
    if head($i$)=$\epsilon$ then
        head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
        add $i$+1 and head($i$+1) as node if necessary
        continue
    $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
    if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
    else              $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
    if $w$ is an edge then
        add a node for $w$
        head($i$+1) = $w$
    else if $w$ is a node then
        head($i$+1) = slowscan($w$,tail($i$))
        add head($i$+1) as node if necessary
    $s$(head($i$)) = $w$
    add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

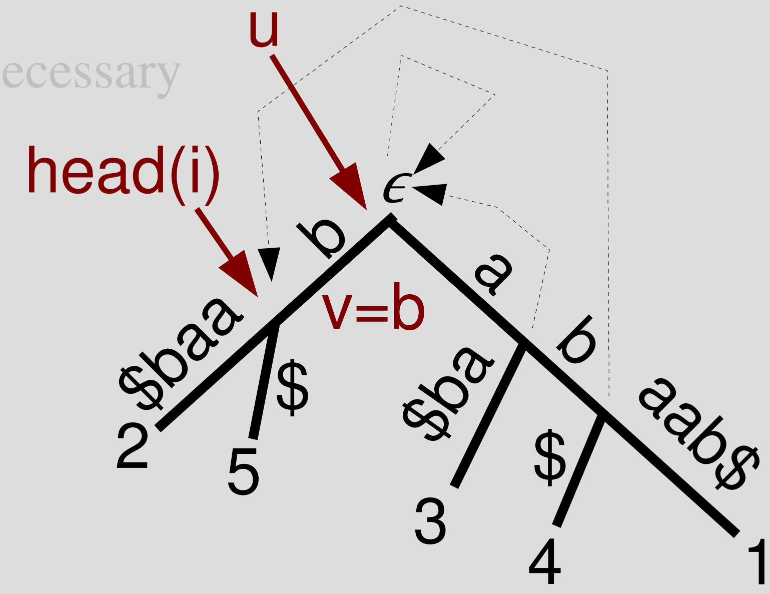
head(4)=ab
tail(4)=$



Example: x = *abaab*, *i*=5, inserting $

```
Construct tree for x[1..n]
for i = 1 to n do
        if head(i)=ε then
                head(i+1) = slowscan(ε,s(tail(i)))
                add i+1 and head(i+1) as node if necessary
                continue
        u = parent(head(i)) ; v = label(u,head(i))
        if u≠ε then w = fastscan(s(u),v)
        else         w = fastscan(ε,v[2..|v|])
        if w is an edge then
                add a node for w
                head(i+1) = w
        else if w is a node then
                head(i+1) = slowscan(w,tail(i))
                add head(i+1) as node if necessary
        s(head(i)) = w
        add leaf i+1 and edge between head(i+1) and i+1
```

head(5)=b
tail(5)=$

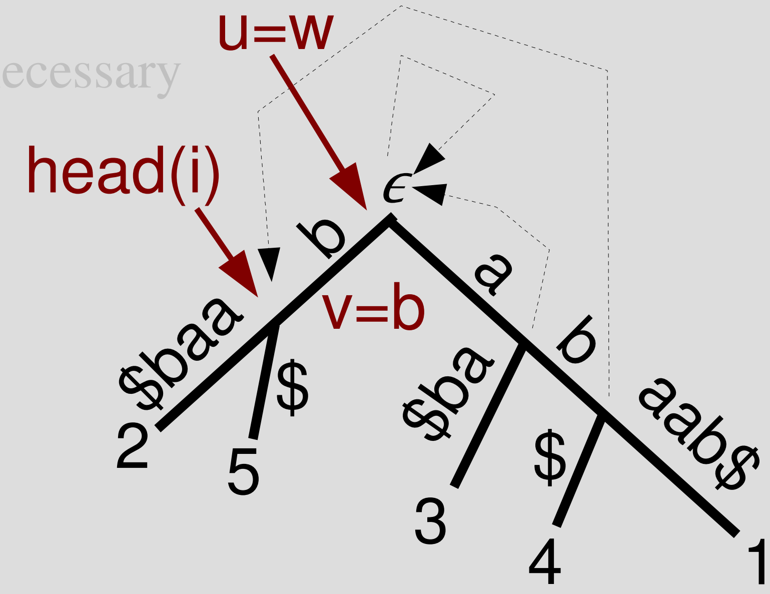


Example: x = *abaab*, *i*=5, inserting $

```
Construct tree for $\mathbf{x}[1..n]$
for $i = 1$ to $n$ do
        if head($i$)=$\epsilon$ then
                head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
                add $i$+1 and head($i$+1) as node if necessary
                continue
        $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
        if $u \neq \epsilon$ then    $w$ = fastscan($s$($u$),$v$)
        else                $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
        if $w$ is an edge then
                add a node for $w$
                head($i$+1) = $w$
        else if $w$ is a node then
                head($i$+1) = slowscan($w$,tail($i$))
                add head($i$+1) as node if necessary
        $s$(head($i$)) = $w$
        add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

v[2..1] = ϵ

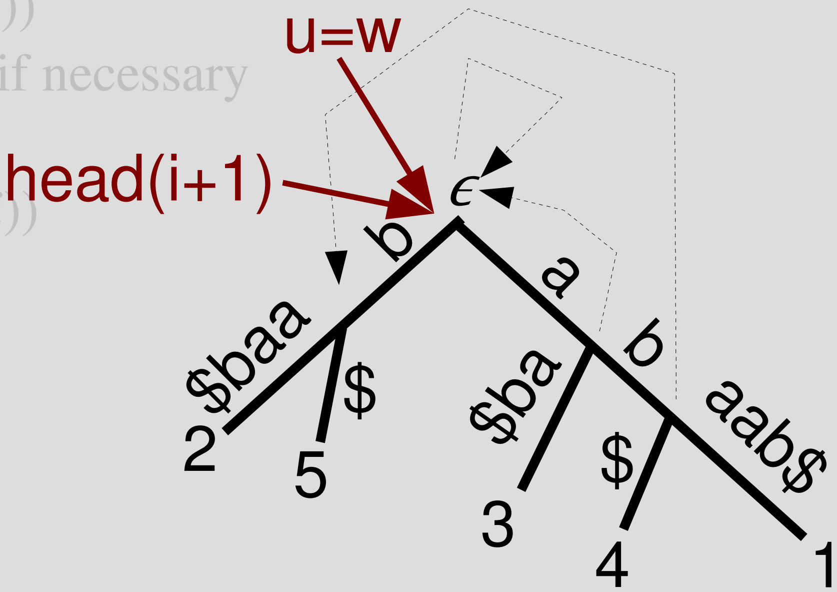
head(5)=b
tail(5)=$



Example: x = *abaab*, *i*=5, inserting $

```
Construct tree for $\mathbf{x}[1..n]$
for $i$ = 1 to $n$ do
    if head($i$)=$\epsilon$ then
        head($i$+1) = slowscan($\epsilon$,$s$(tail(i)))
        add $i$+1 and head($i$+1) as node if necessary
        continue
    $u$ = parent(head($i$)) ; $v$ = label($u$,head($i$))
    if $u \neq \epsilon$ then $w$ = fastscan($s$($u$),$v$)
    else            $w$ = fastscan($\epsilon$,$v$[2..|$v$|])
    if $w$ is an edge then
        add a node for $w$
        head($i$+1) = $w$
    else if $w$ is a node then
        head($i$+1) = slowscan($w$,tail($i$))
        add head($i$+1) as node if necessary
    $s$(head($i$)) = $w$
    add leaf $i$+1 and edge between head($i$+1) and $i$+1
```

head(5)=b
tail(5)=$



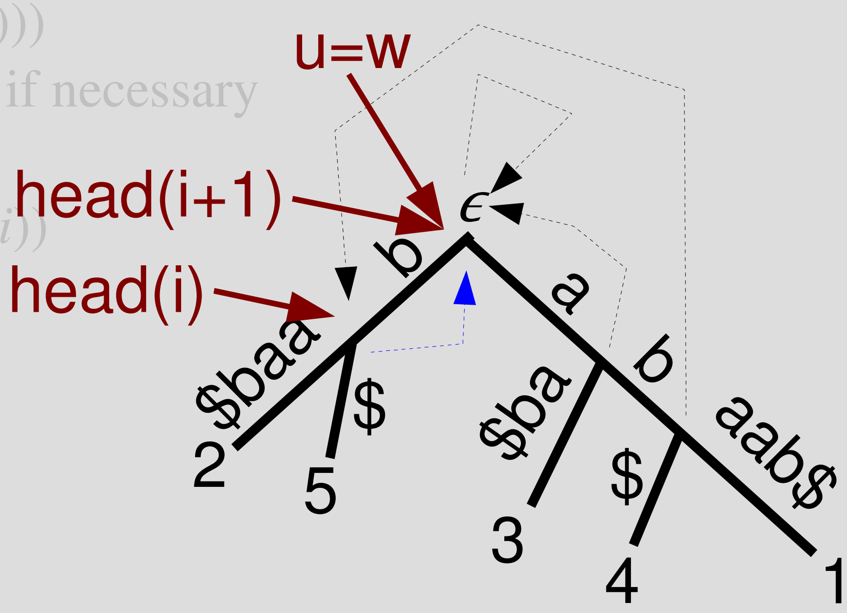
u=w

head(i+1)

Example: x = *abaab*, *i*=5, inserting $

```
Construct tree for x[1..n]
for i = 1 to n do
    if head(i)=$\epsilon$ then
        head(i+1) = slowscan($\epsilon$,s(tail(i)))
        add i+1 and head(i+1) as node if necessary
        continue
    u = parent(head(i)) ; v = label(u,head(i))
    if u$\neq\epsilon$ then w = fastscan(s(u),v)
    else            w = fastscan($\epsilon$,v[2..|v|])
    if w is an edge then
        add a node for w
        head(i+1) = w
    else if w is a node then
        head(i+1) = slowscan(w,tail(i))
        add head(i+1) as node if necessary
    s(head(i)) = w
    add leaf i+1 and edge between head(i+1) and i+1
```

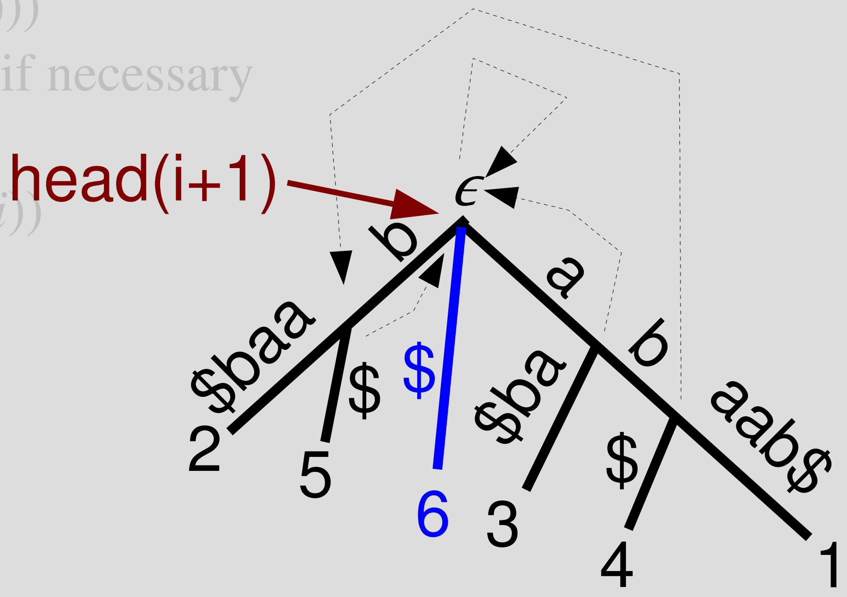
head(5)=b
tail(5)=$



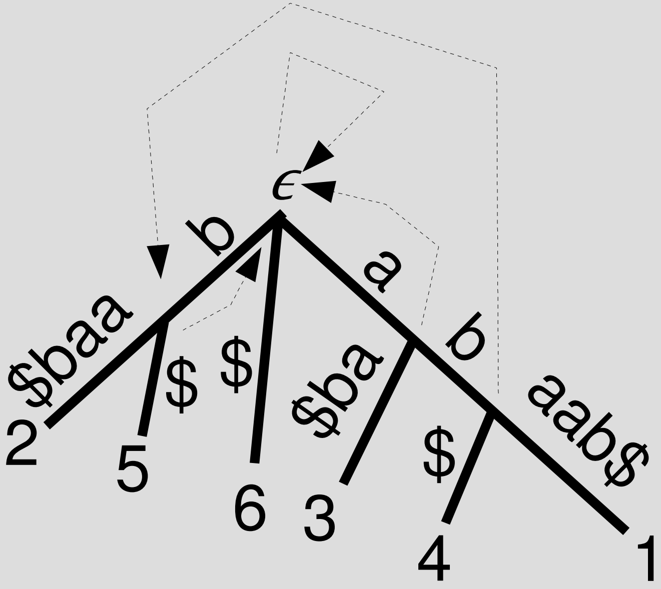
Example: x = *abaab*, *i*=5, inserting $

head(5)=b
tail(5)=$

```
Construct tree for x[1..n]
for i = 1 to n do
    if head(i)=ϵ then
        head(i+1) = slowscan(ϵ,s(tail(i)))
        add i+1 and head(i+1) as node if necessary
        continue
    u = parent(head(i)) ; v = label(u,head(i))
    if u≠ϵ then w = fastscan(s(u),v)
    else        w = fastscan(ϵ,v[2..|v|])
    if w is an edge then
        add a node for w
        head(i+1) = w
    else if w is a node then
        head(i+1) = slowscan(w,tail(i))
        add head(i+1) as node if necessary
    s(head(i)) = w
    add leaf i+1 and edge between head(i+1) and i+1
```



Done


ϵ
b
a
$baa
$
$
$ba
b
$
aab$
2
5
6
3
4
1