Forelesning 8

Bonusmateriale

Ting som ikke ble med i forelesningen, men som kanskje kan være av interesse

Traversering › DFS ›

Parentesteoremet

Noder oppdages før og avsluttes etter sine etterkommere

mlh@ntnu.no

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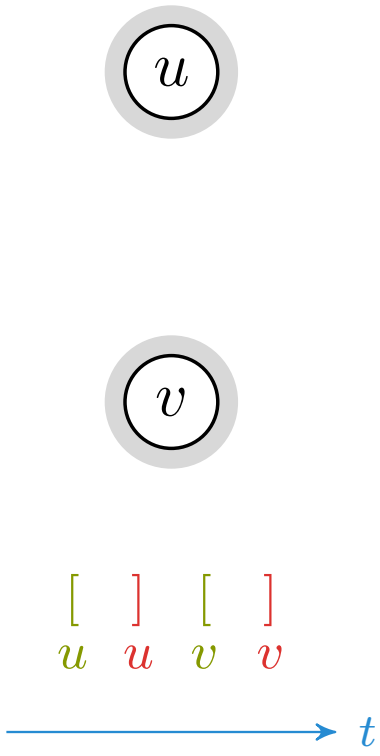

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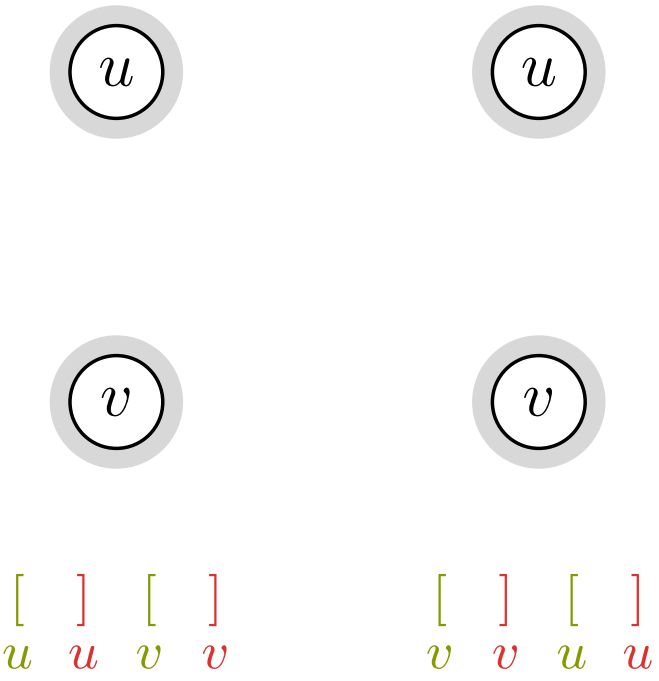
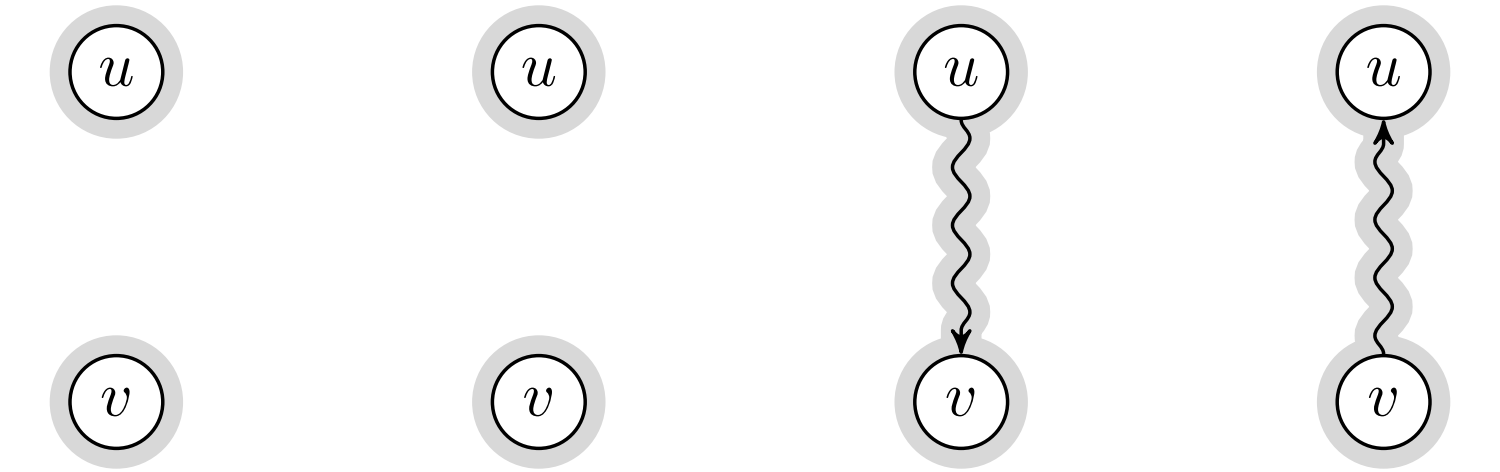


Noder oppdages før og avsluttes etter sine etterkommere

mlh@ntnu.no

Obs: Etterkommere i DFS-skogen!

Dvs., det kan godt hende det går stier mellom u og v i grafen, men at ingen av dem er etterkommer av den andre i DFS-skogen.



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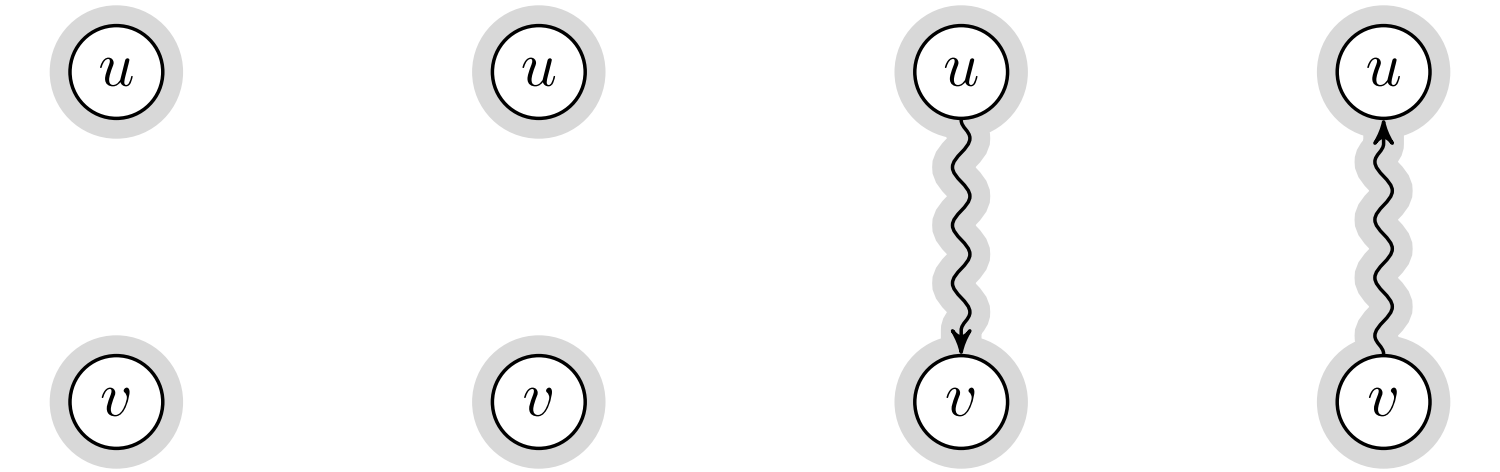
Noder oppdages før og avsluttes etter sine etterkommere

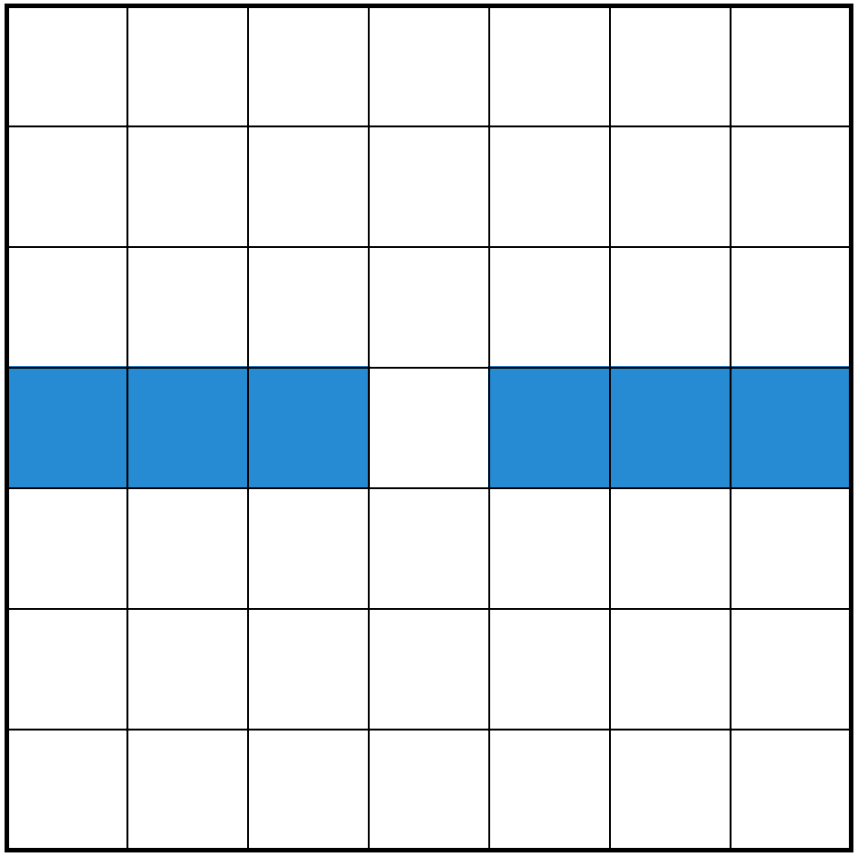


Dette er de eneste mulighetene!

Flood-fill

Klassisk DFS-aktig eksempel

Fargelegging av deler av et bilde



DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest

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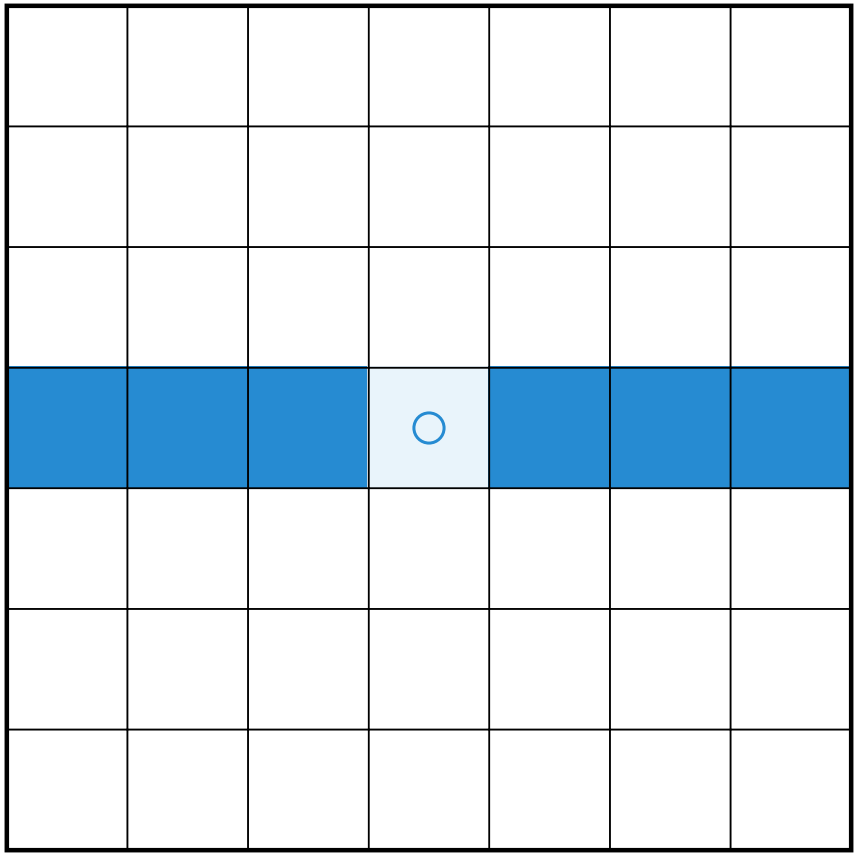

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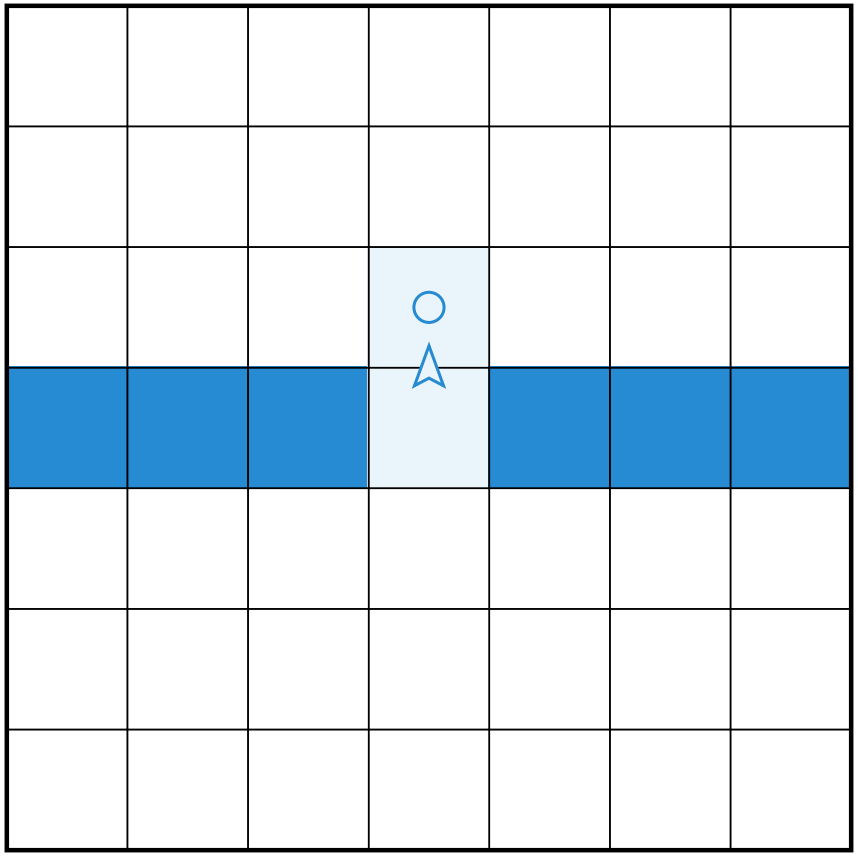
mlh@ntnu.no



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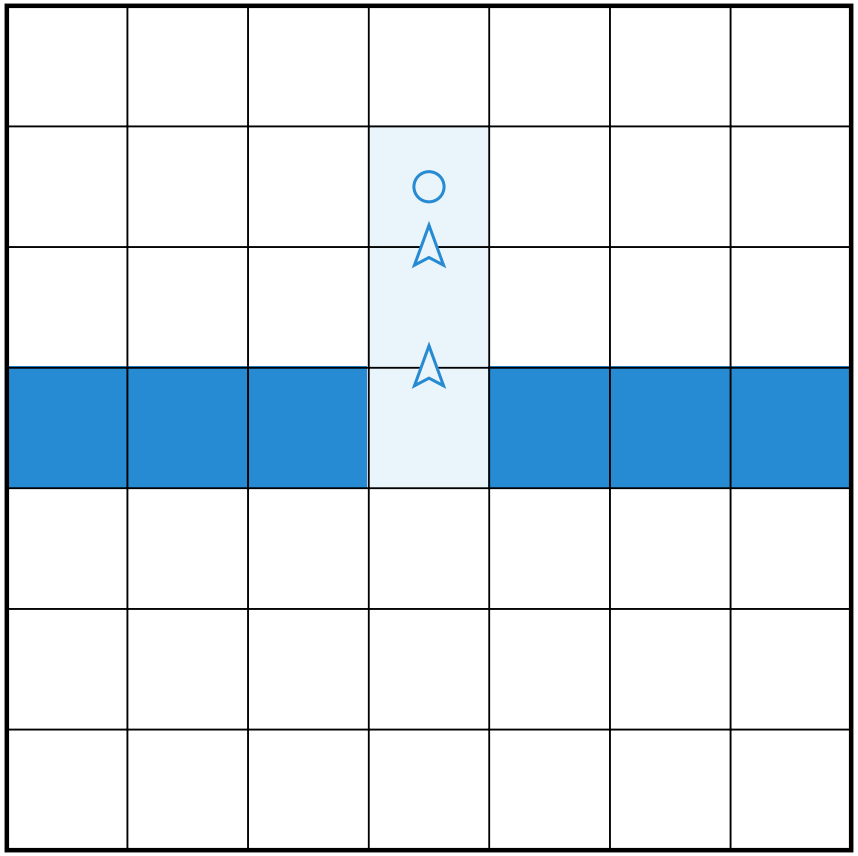
mlh@ntnu.no



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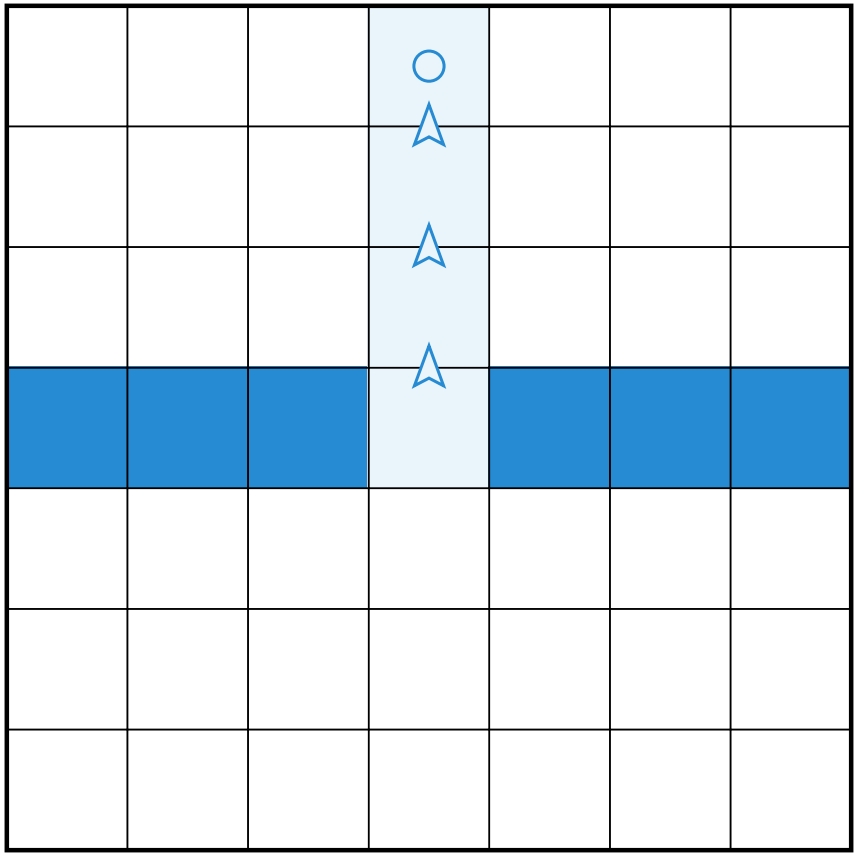
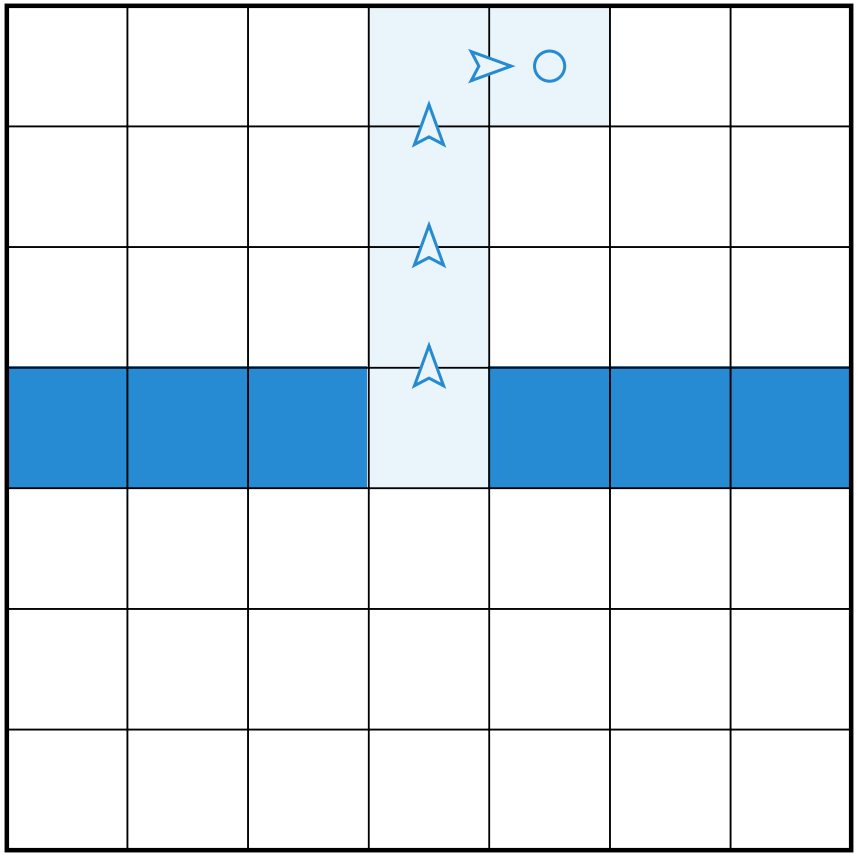
mlh@ntnu.no



DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest

mlh@ntnu.no



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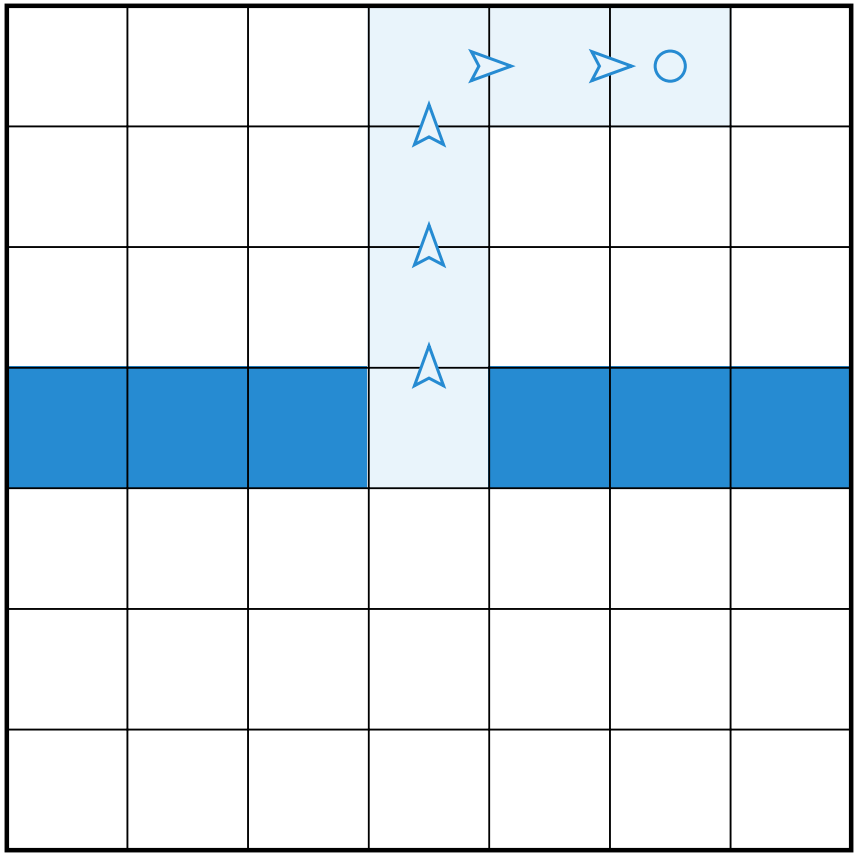

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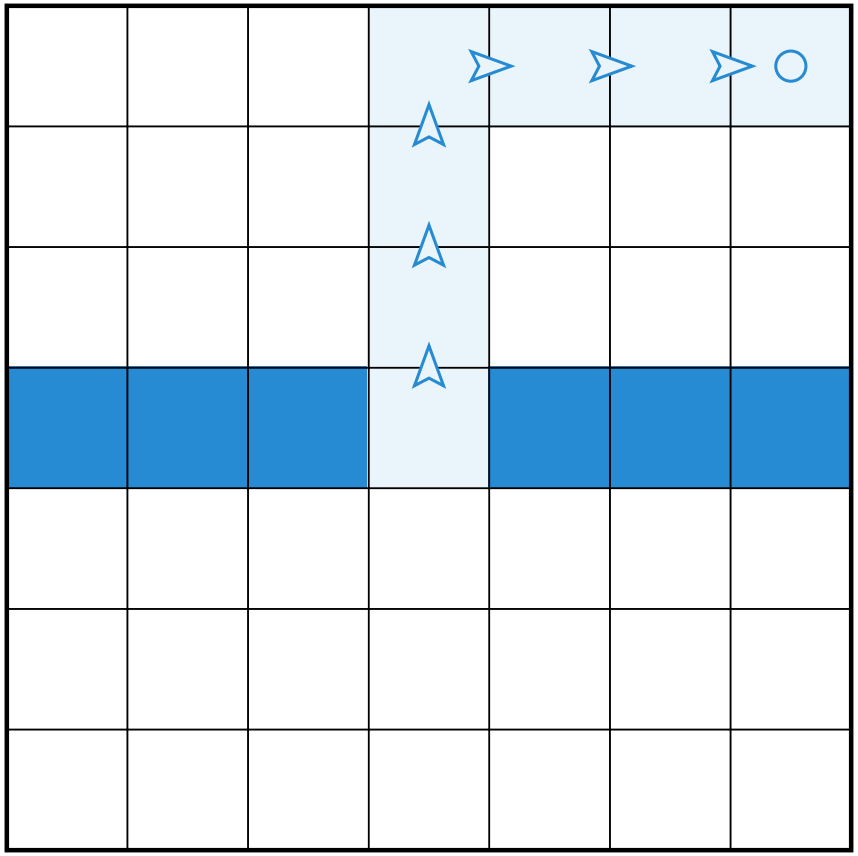

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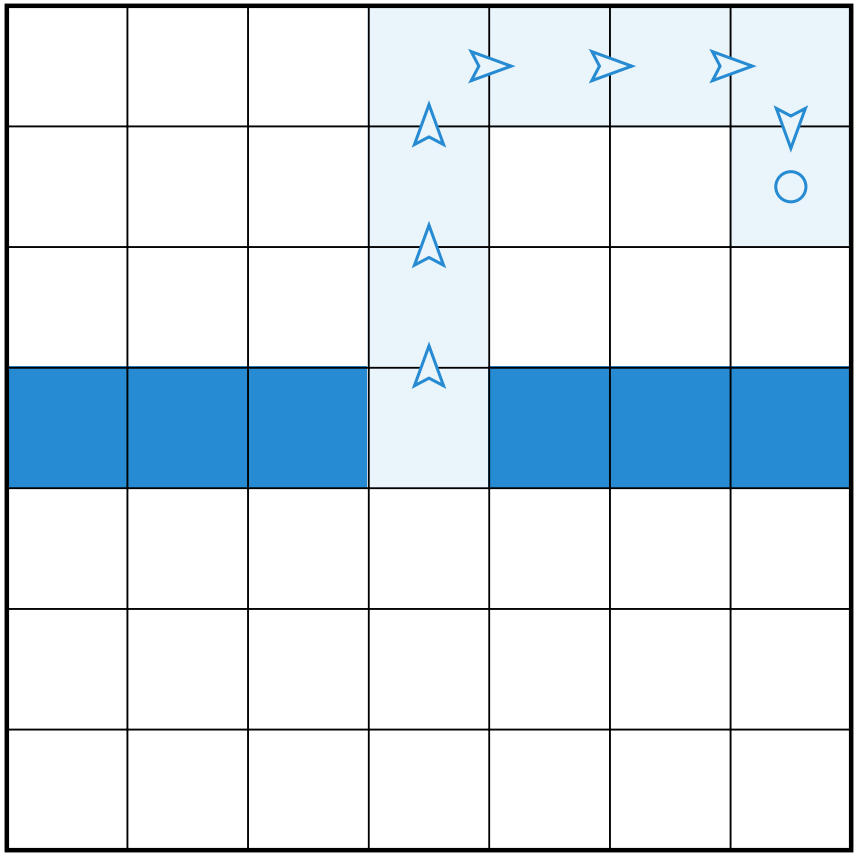

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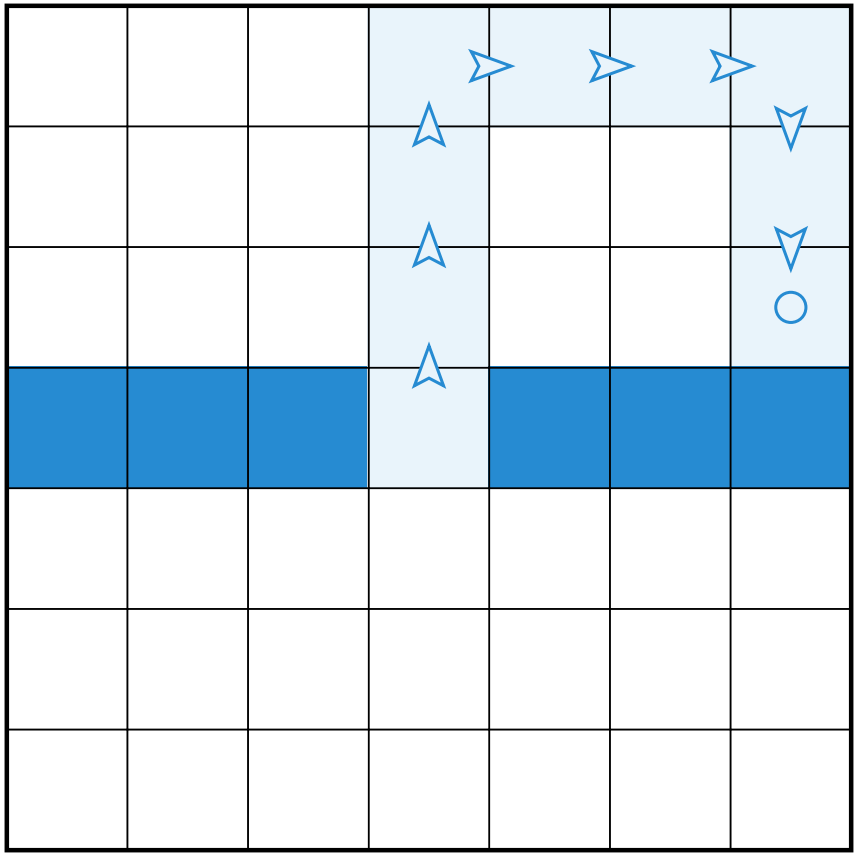

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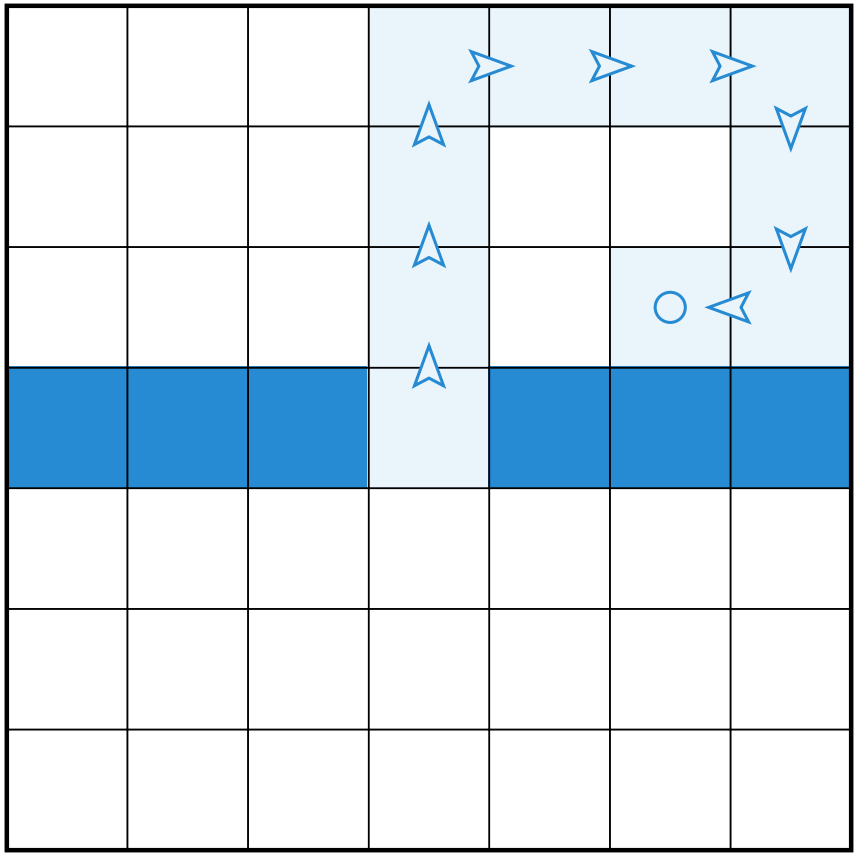

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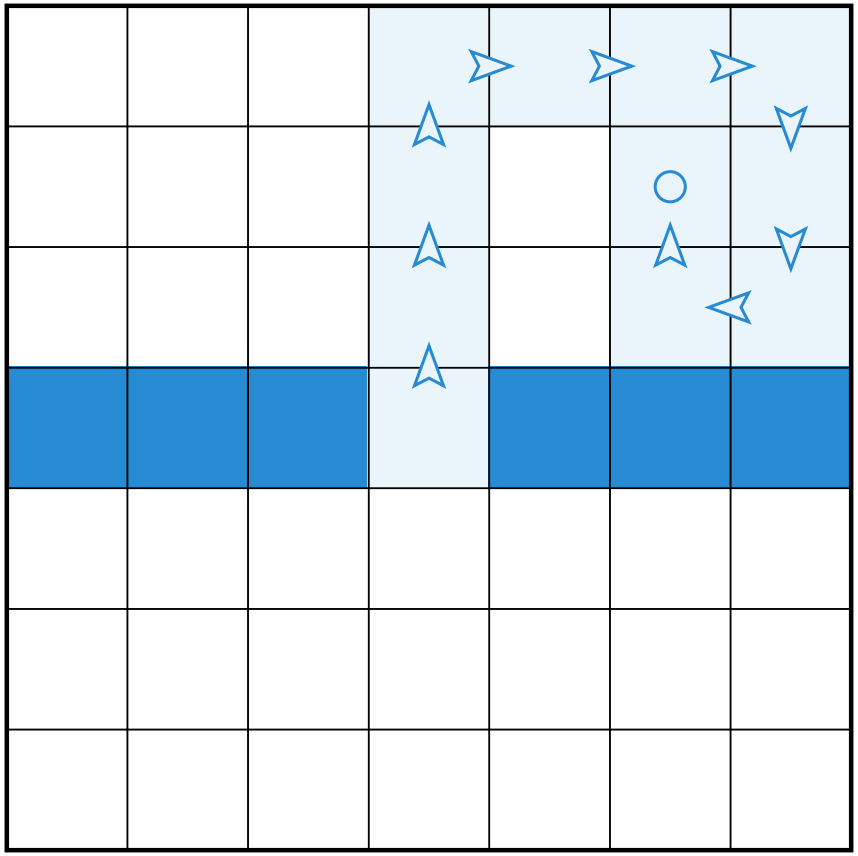

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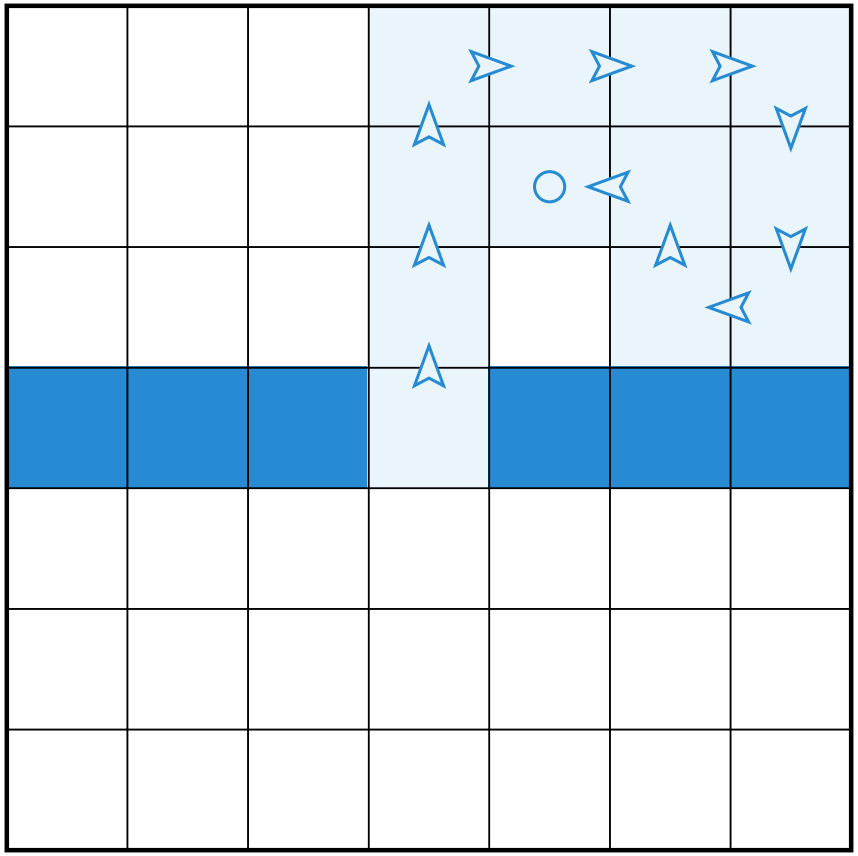

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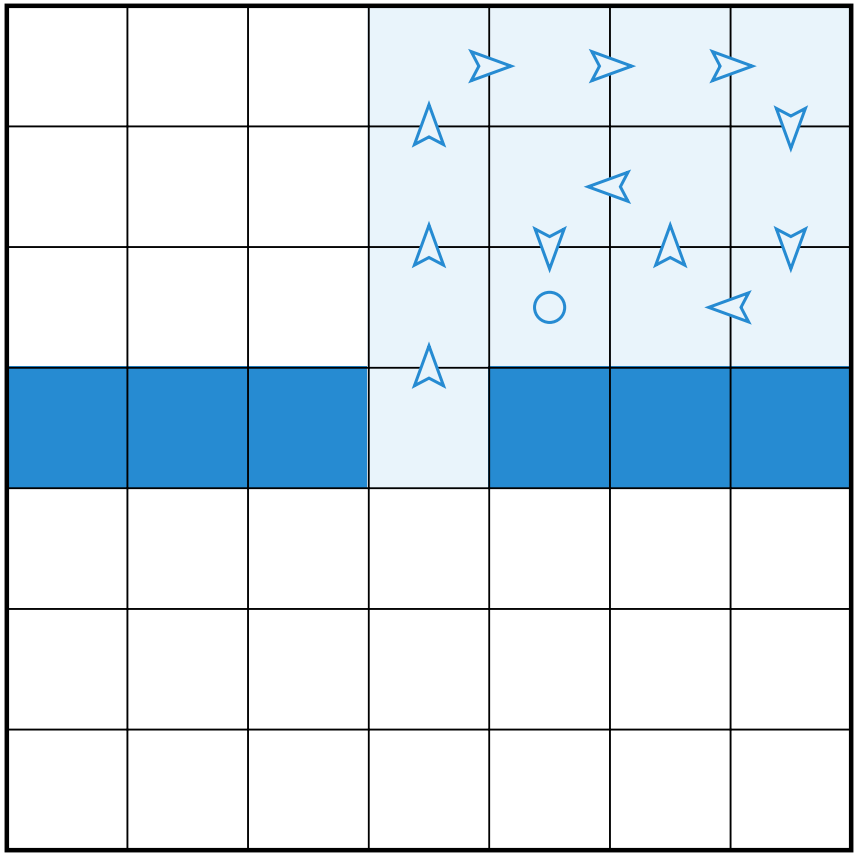

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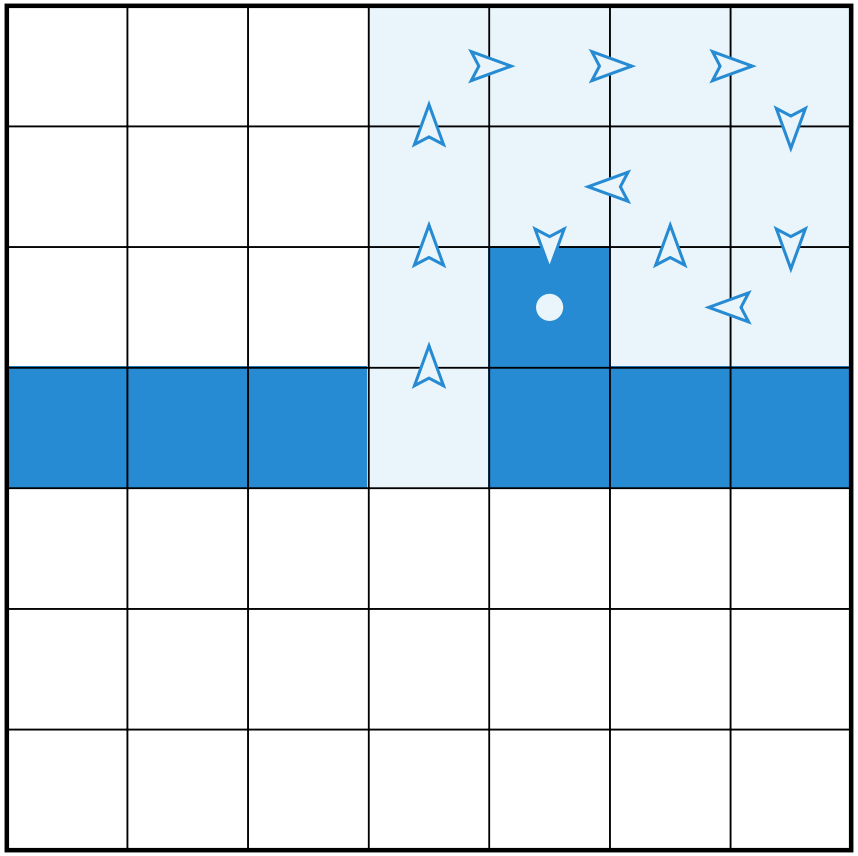

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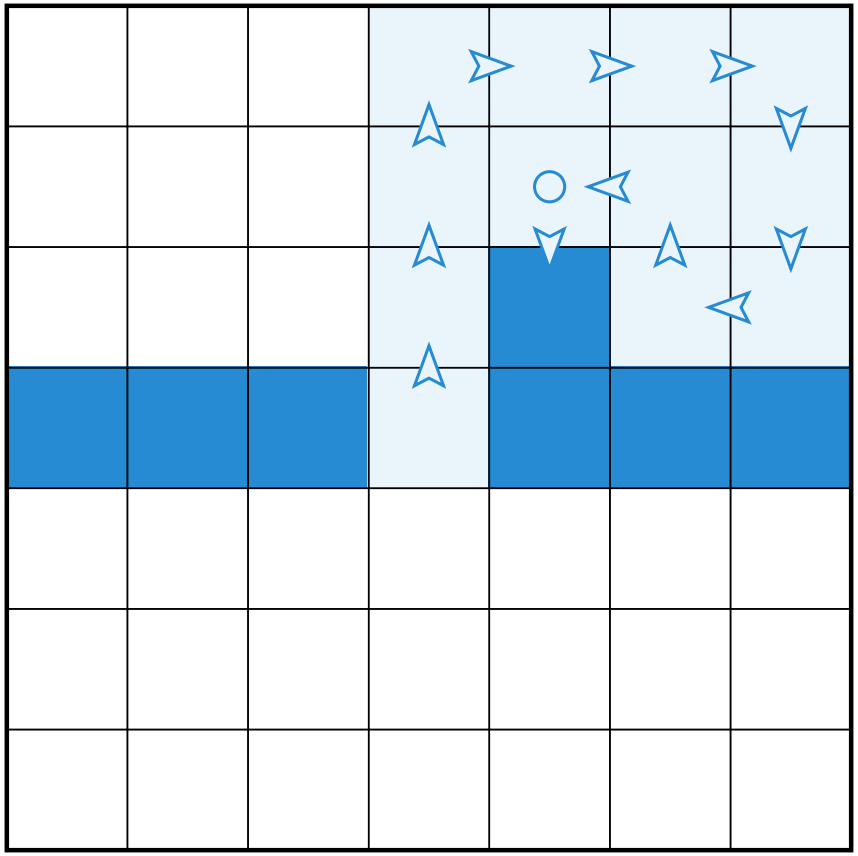

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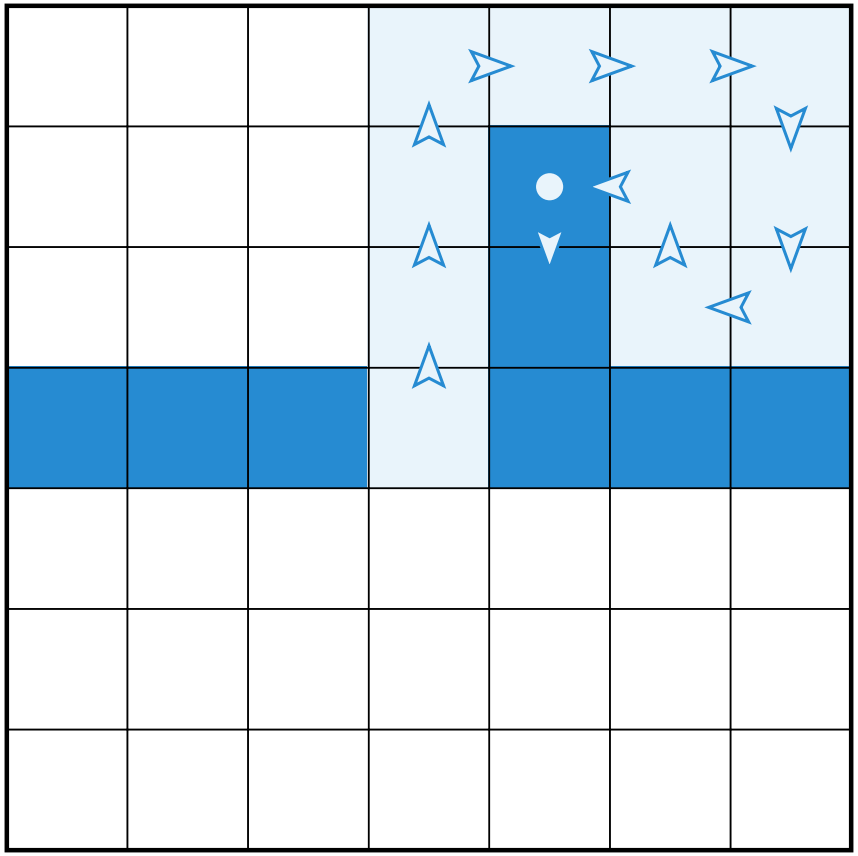

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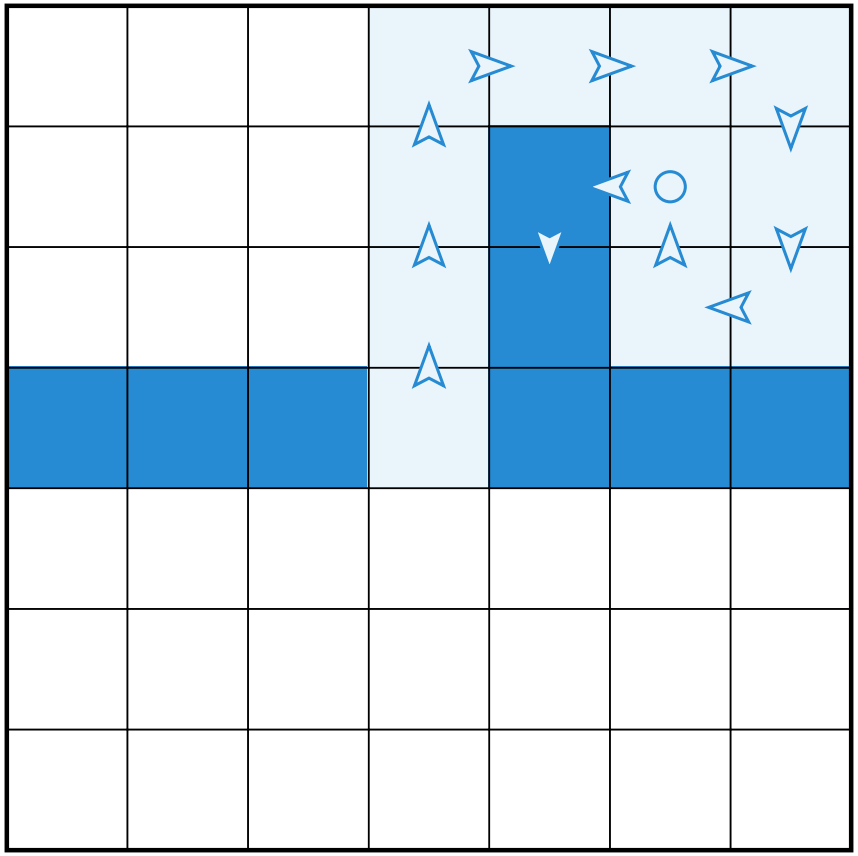

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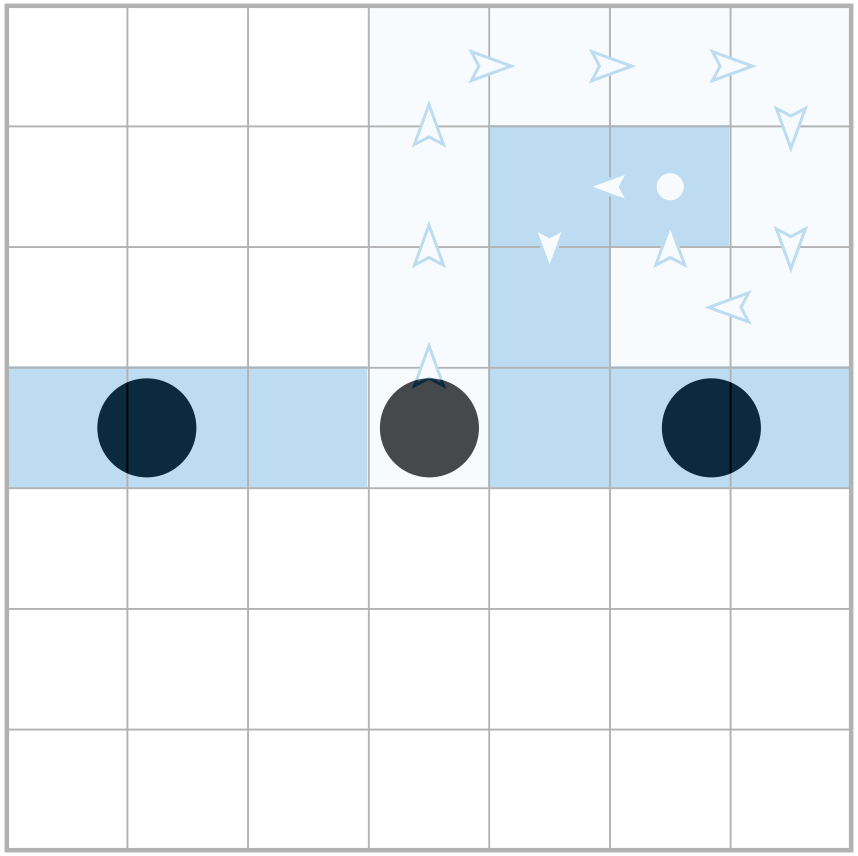

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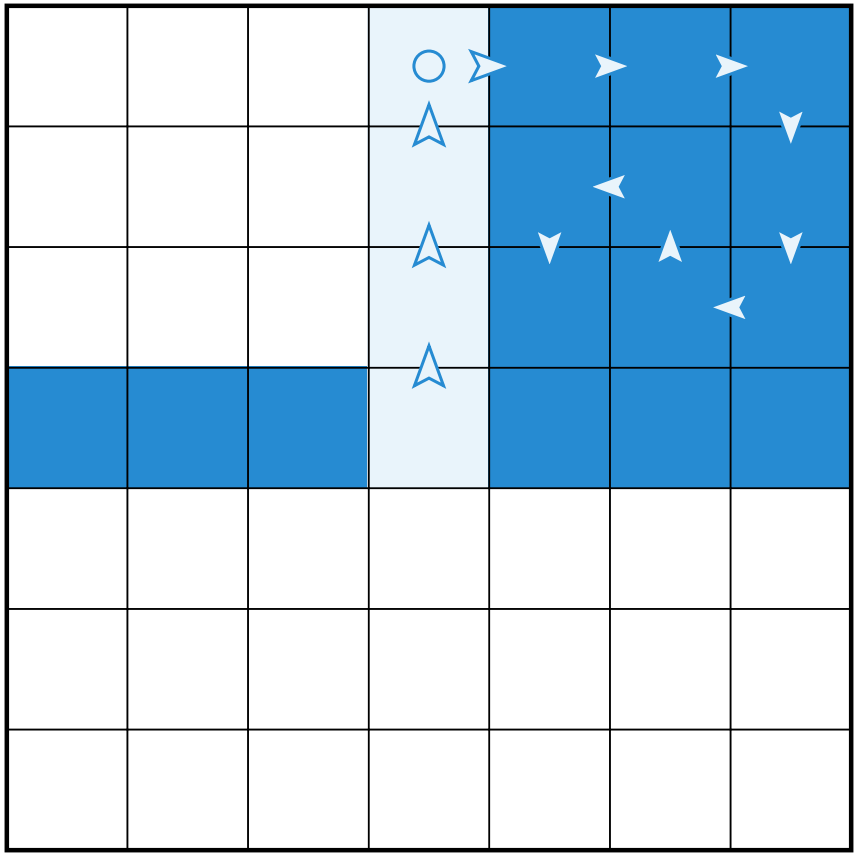

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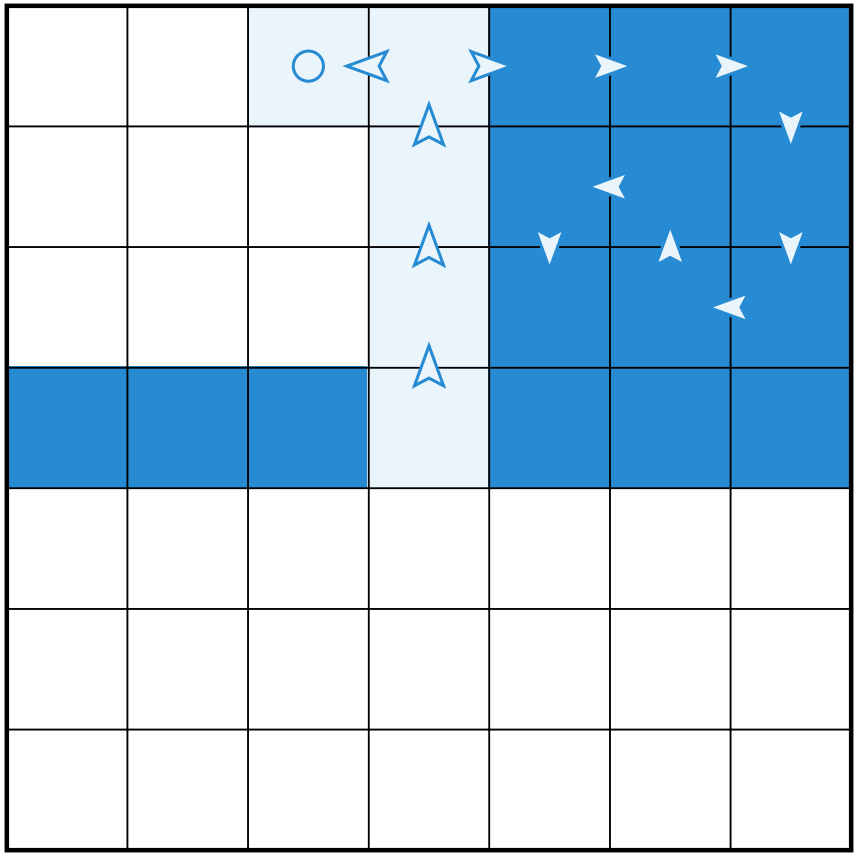

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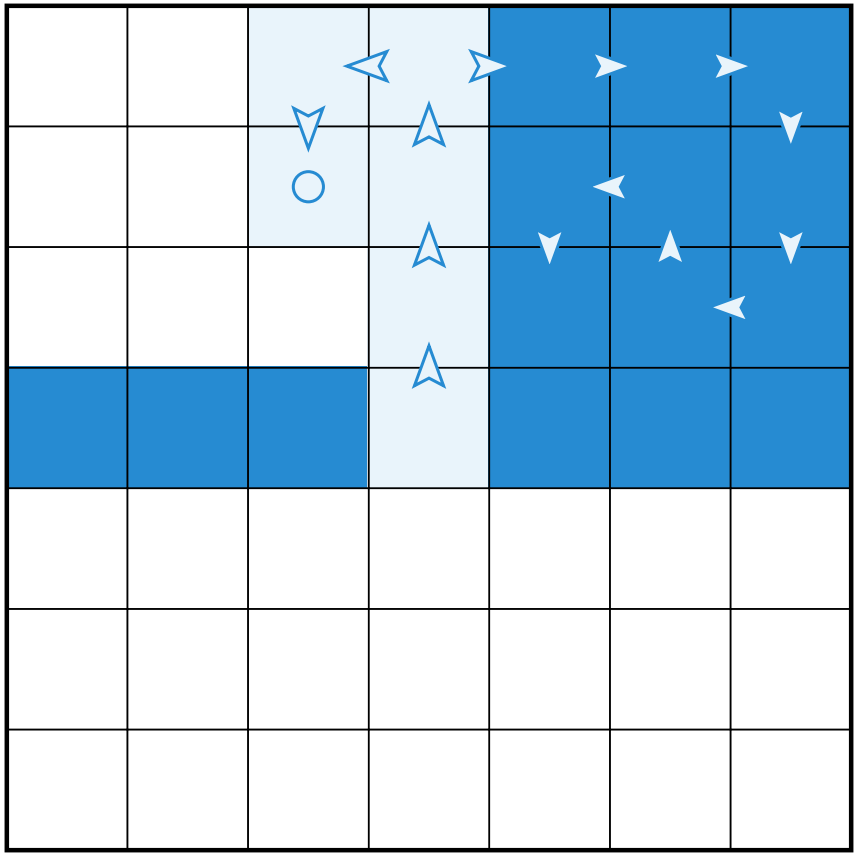

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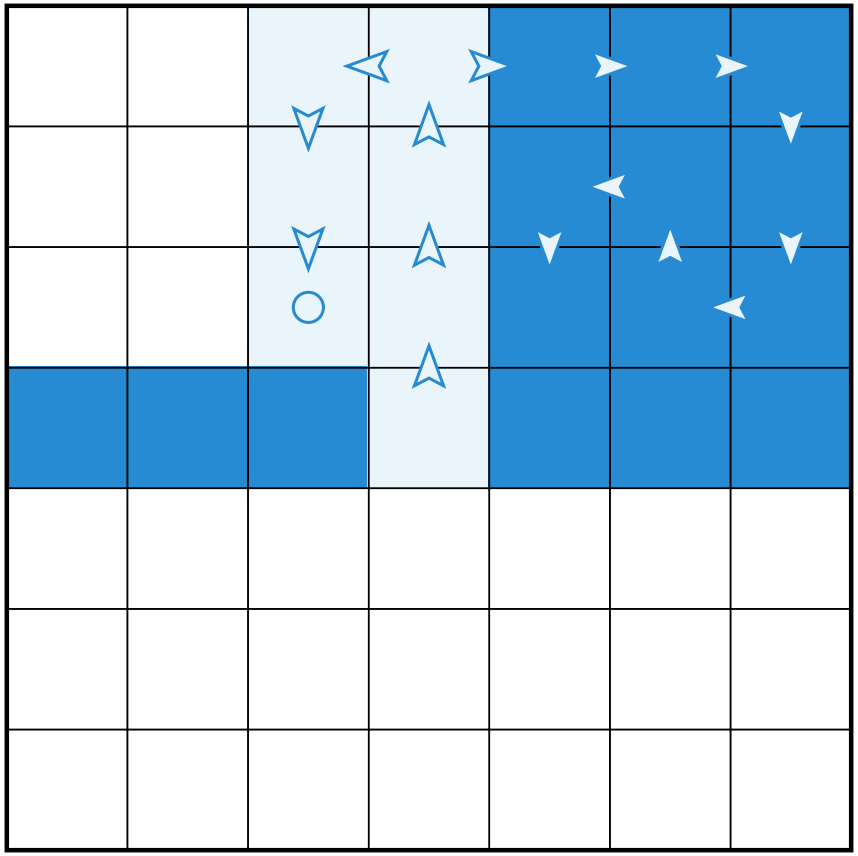

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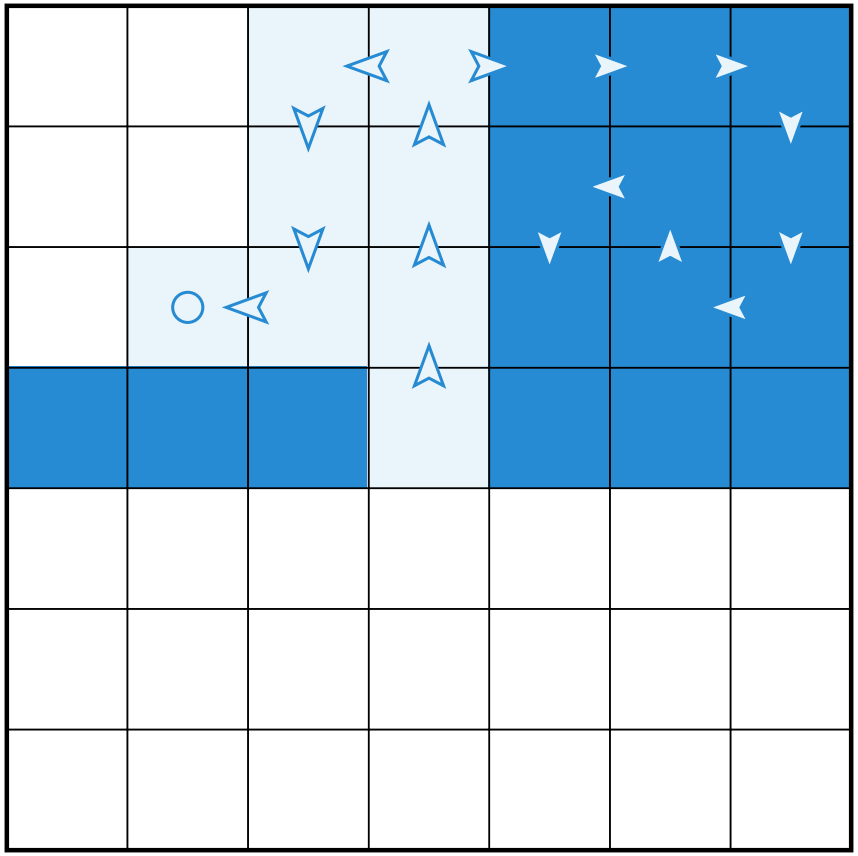

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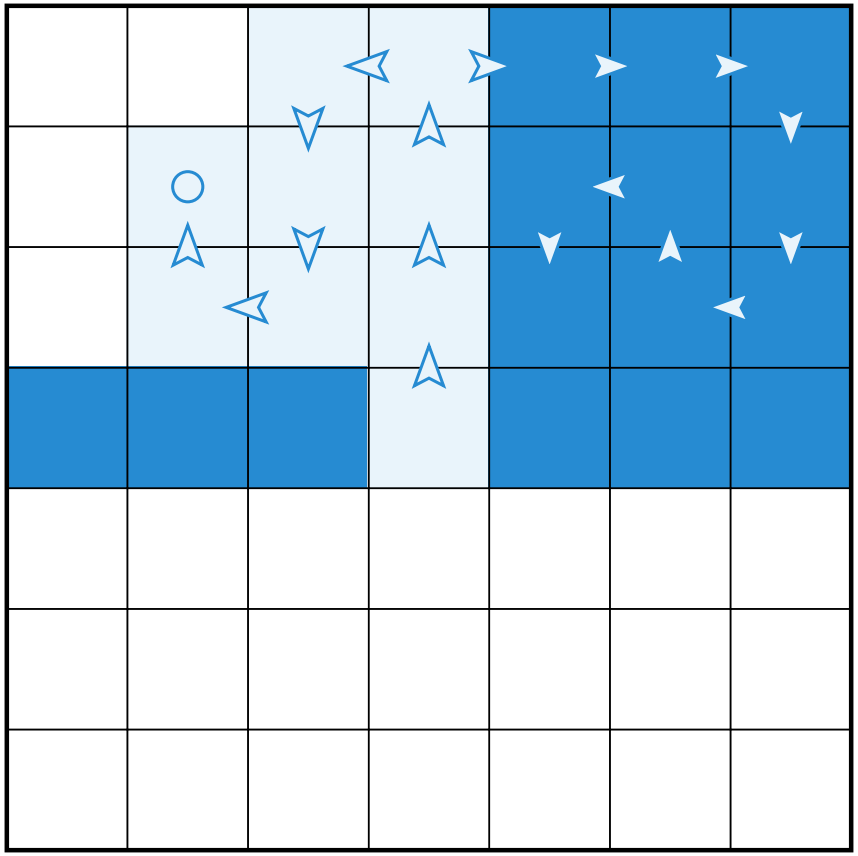

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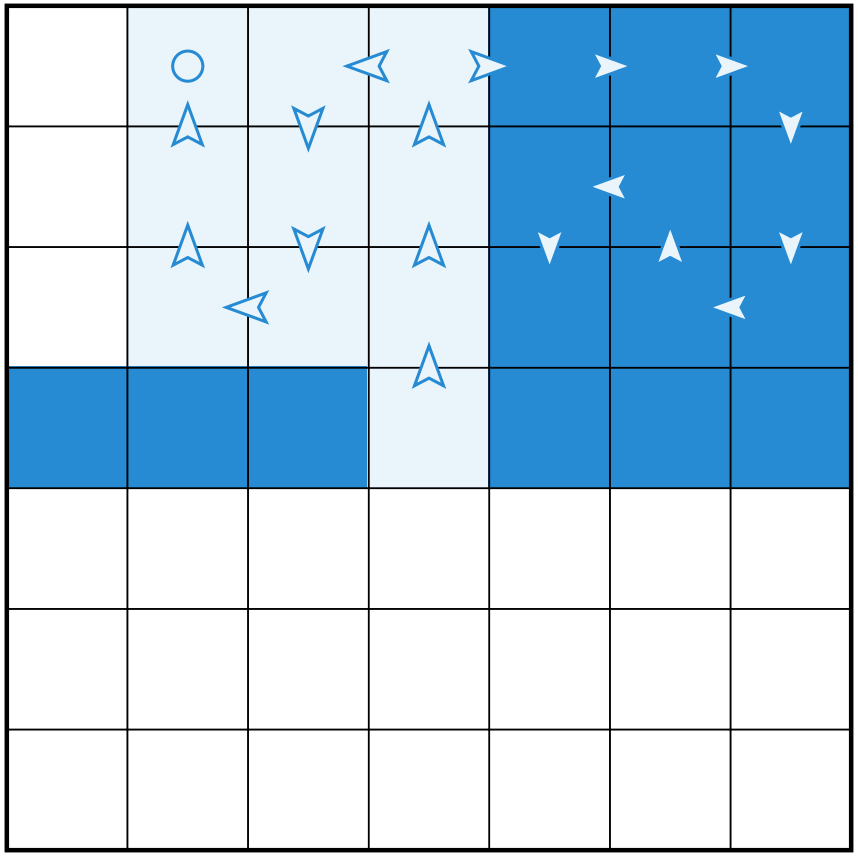

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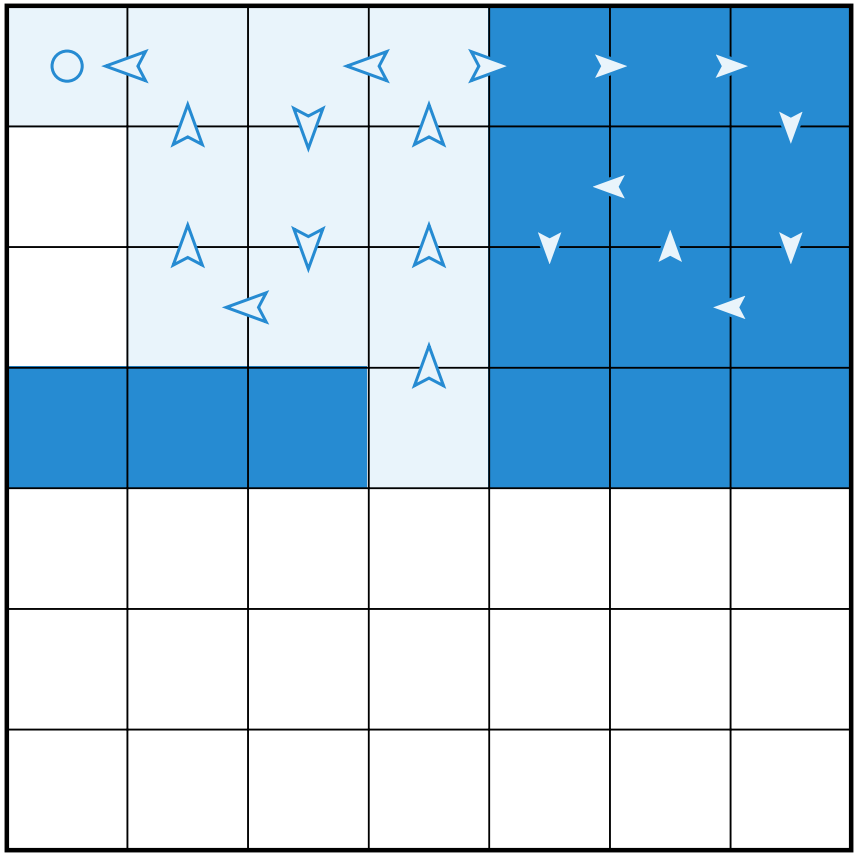

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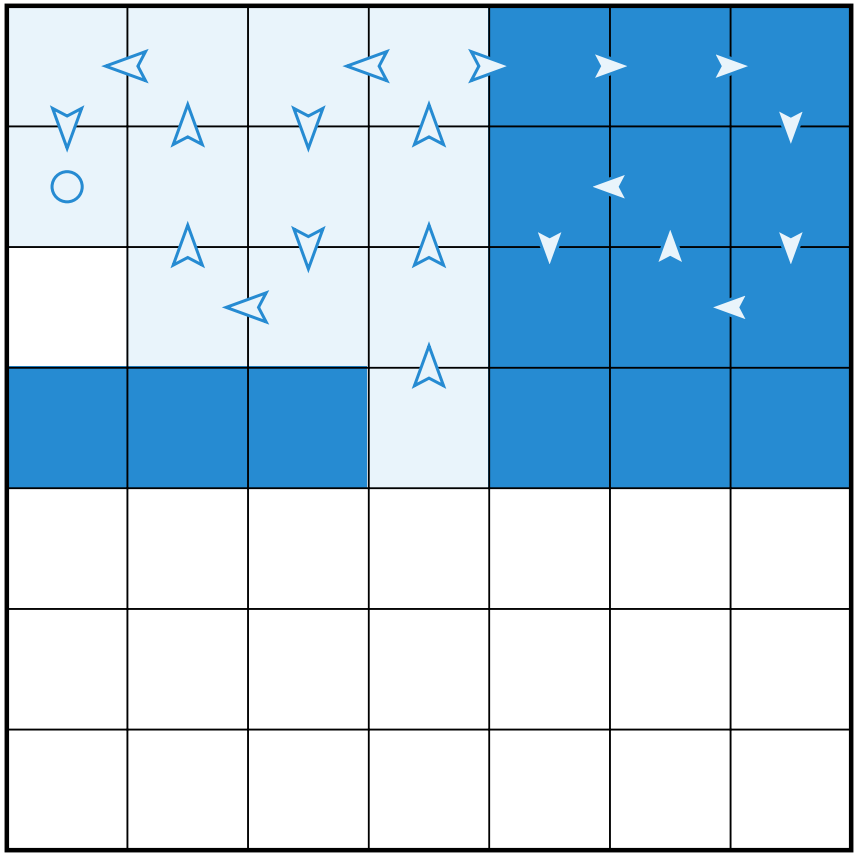

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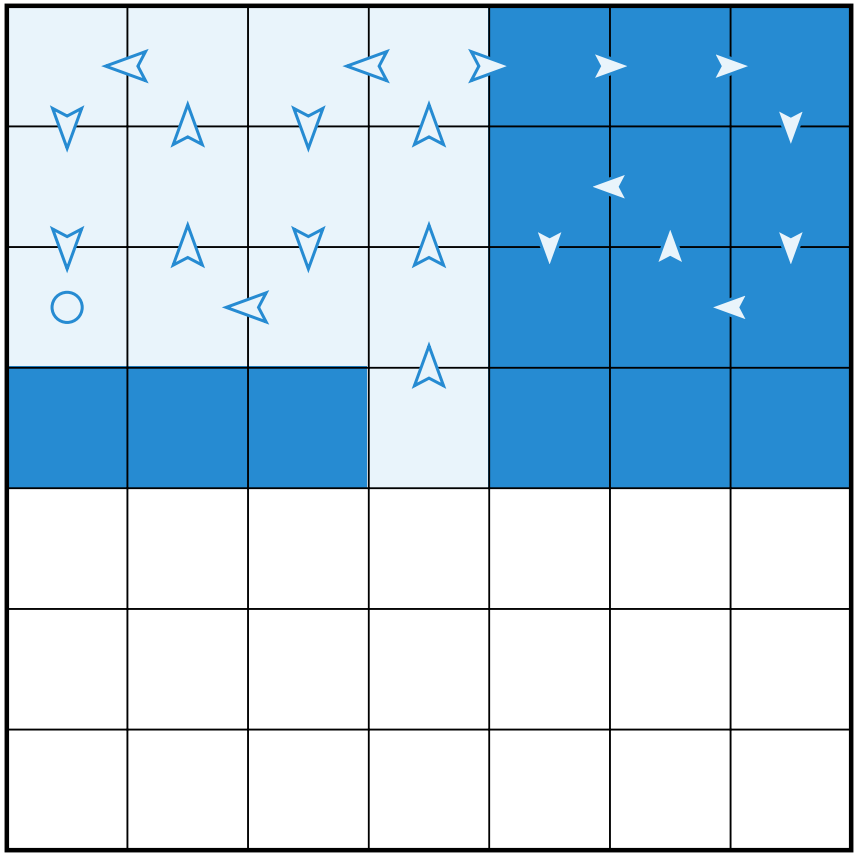

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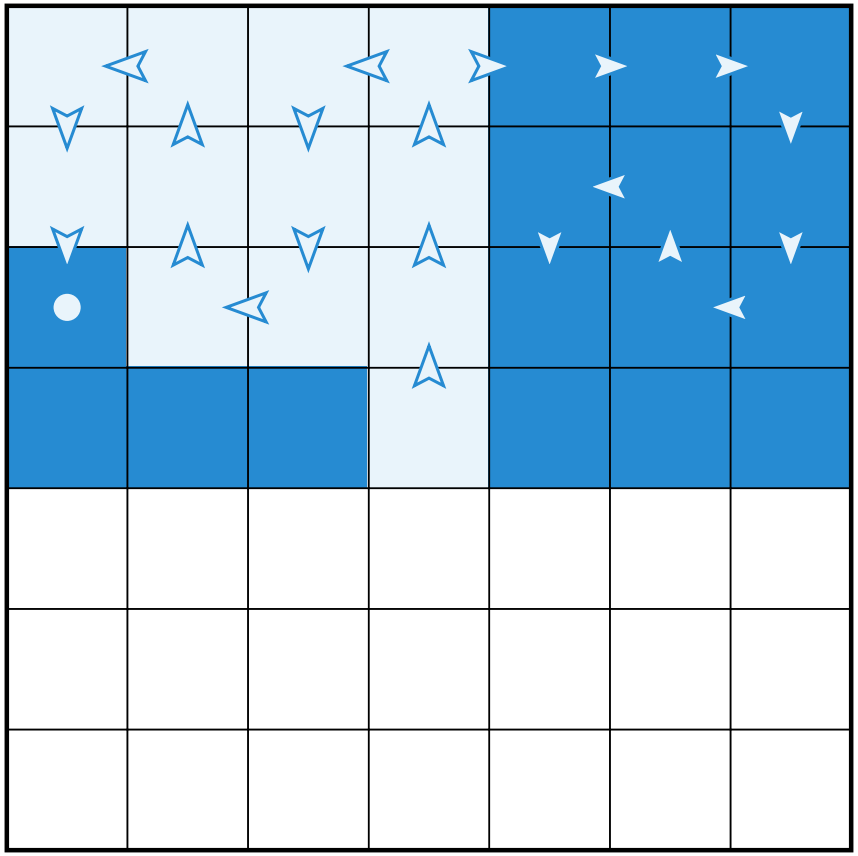

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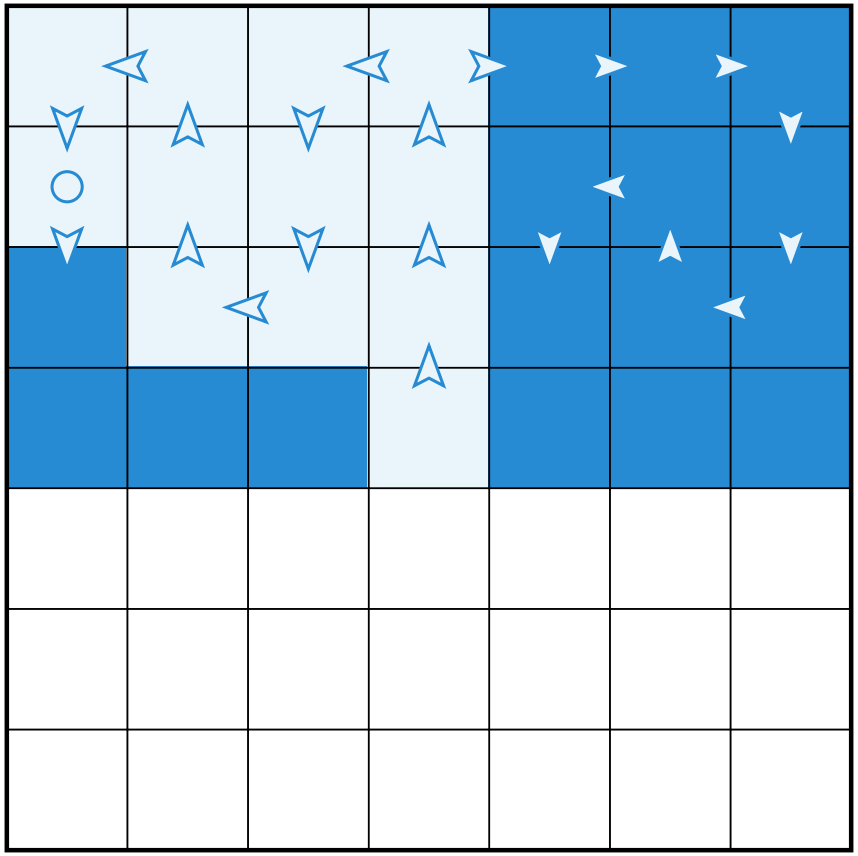

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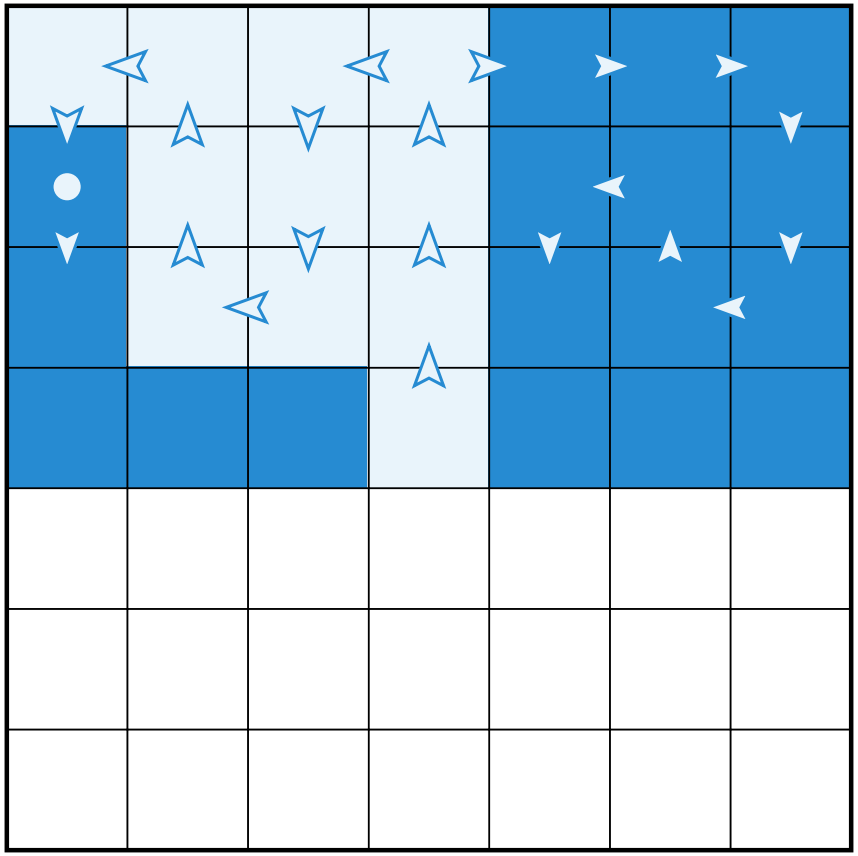

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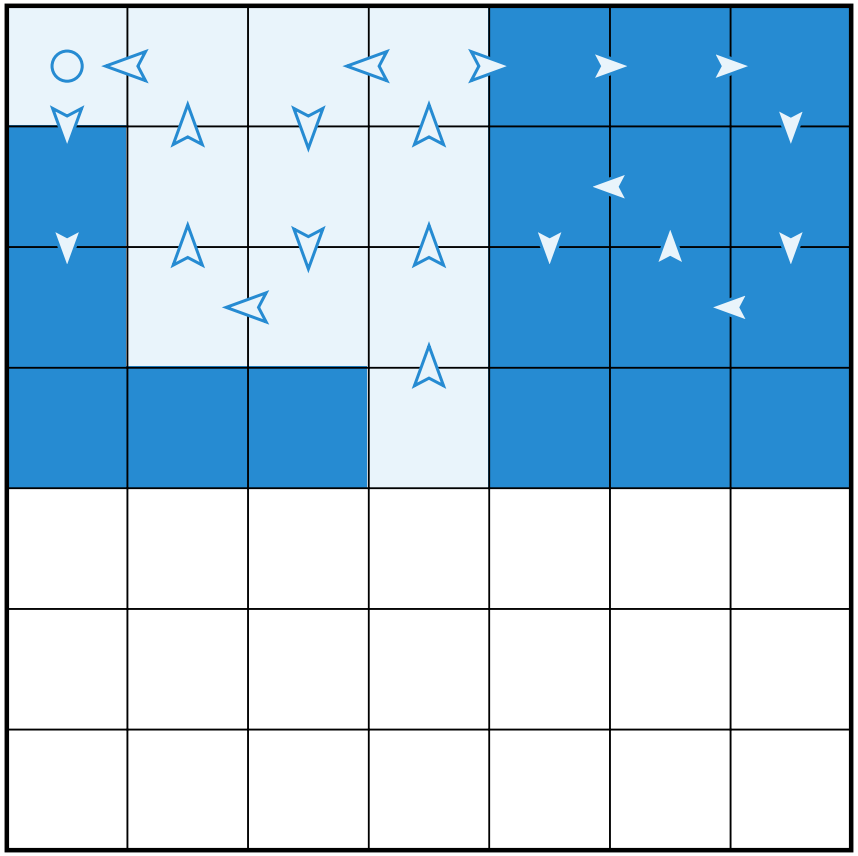

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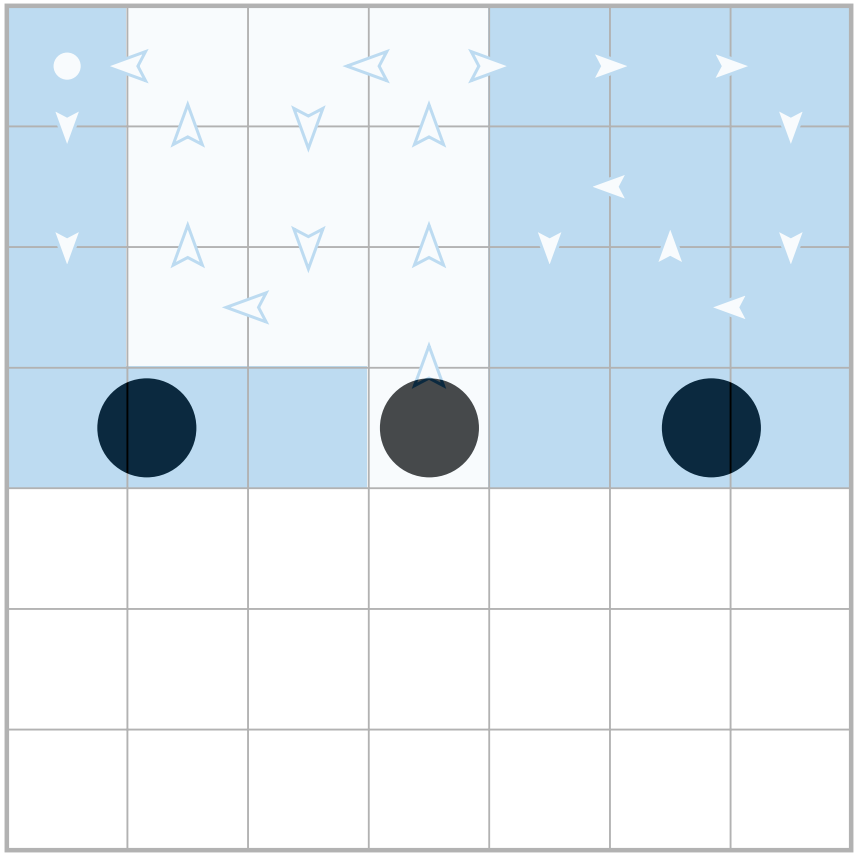

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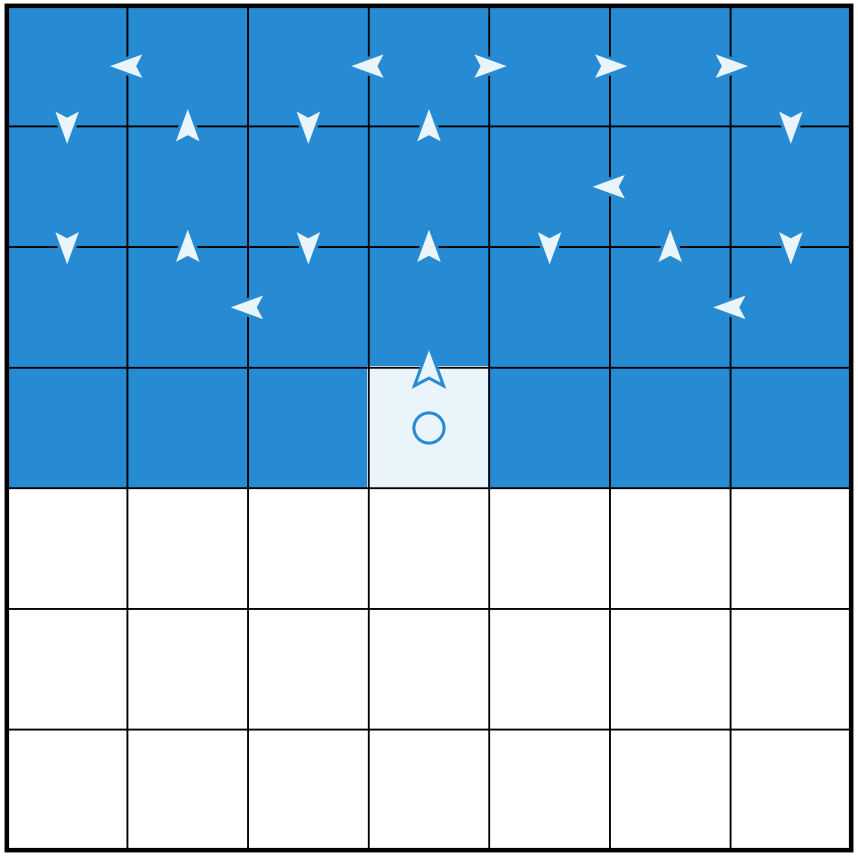

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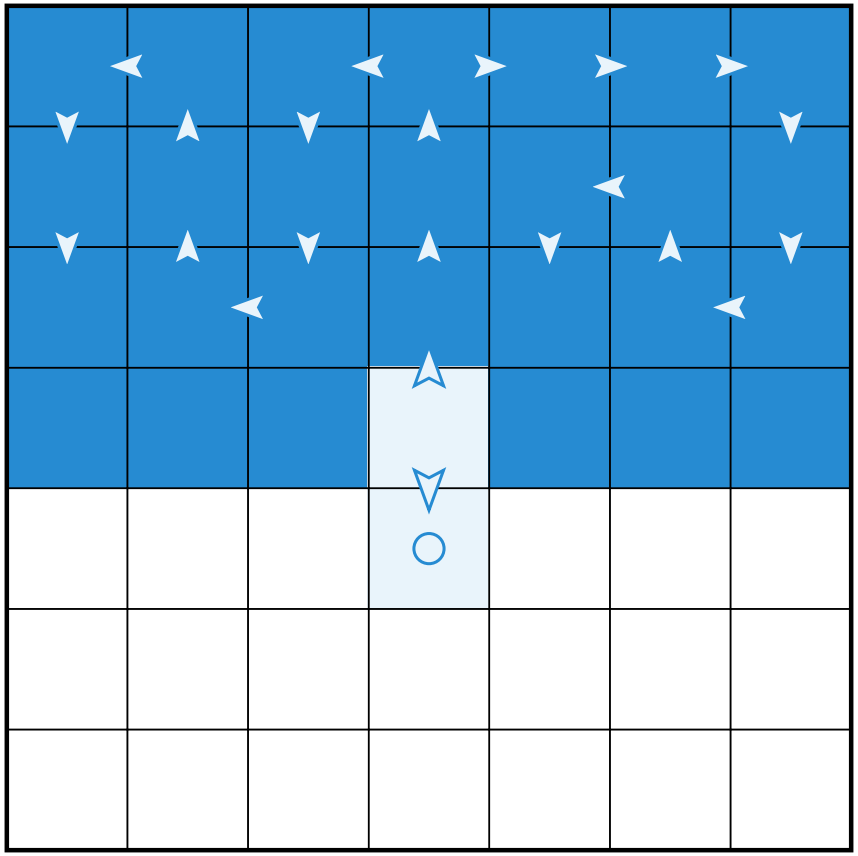

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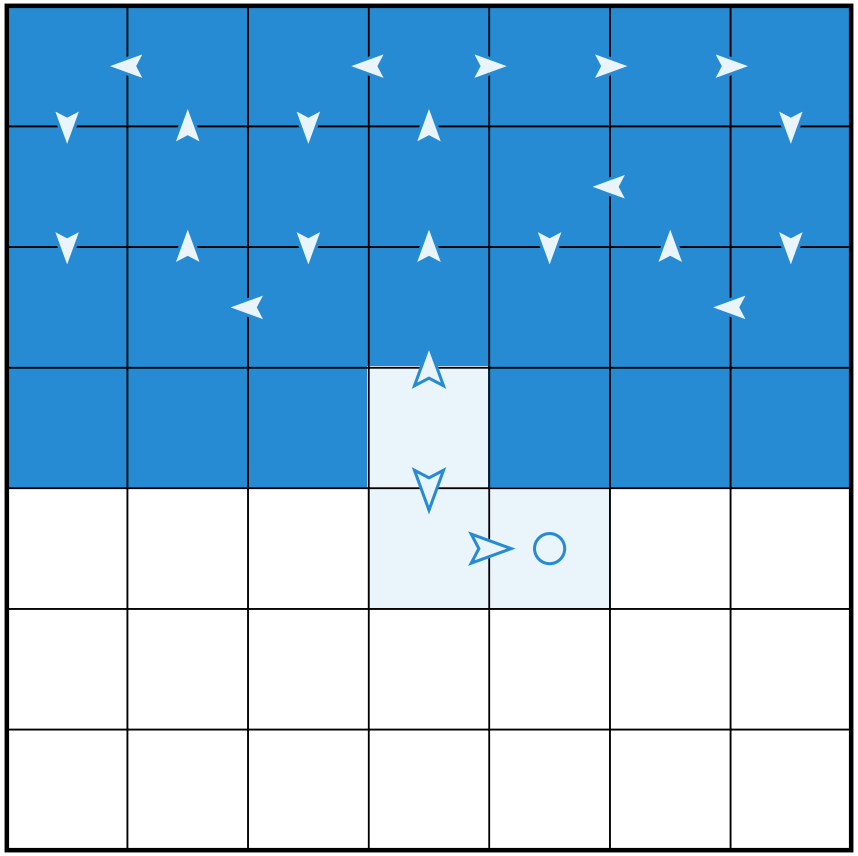

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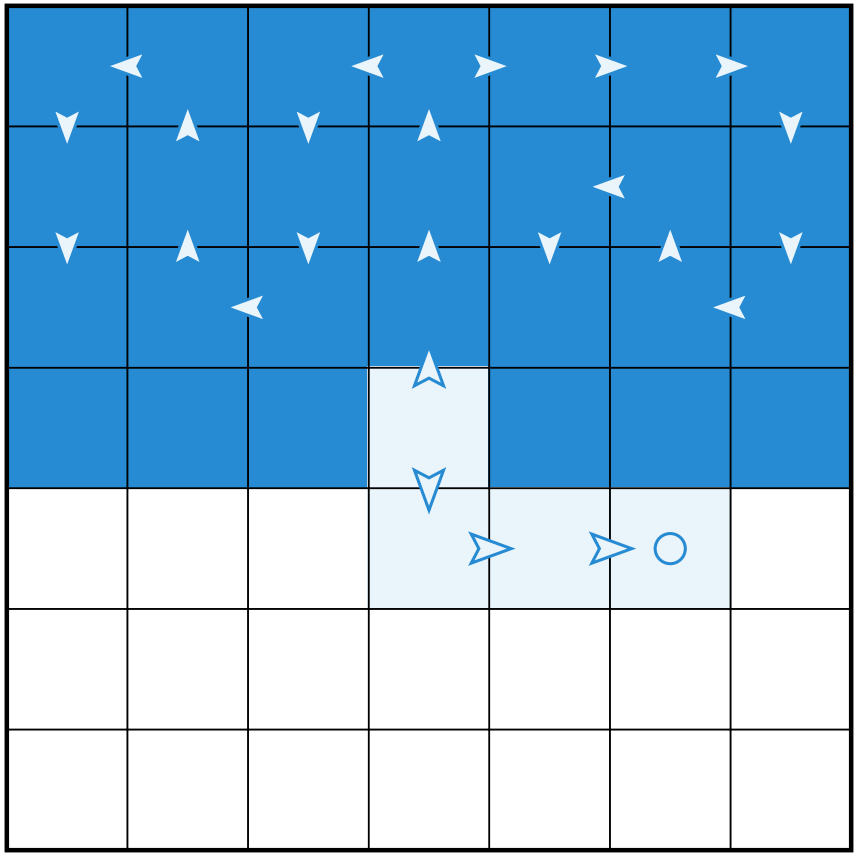

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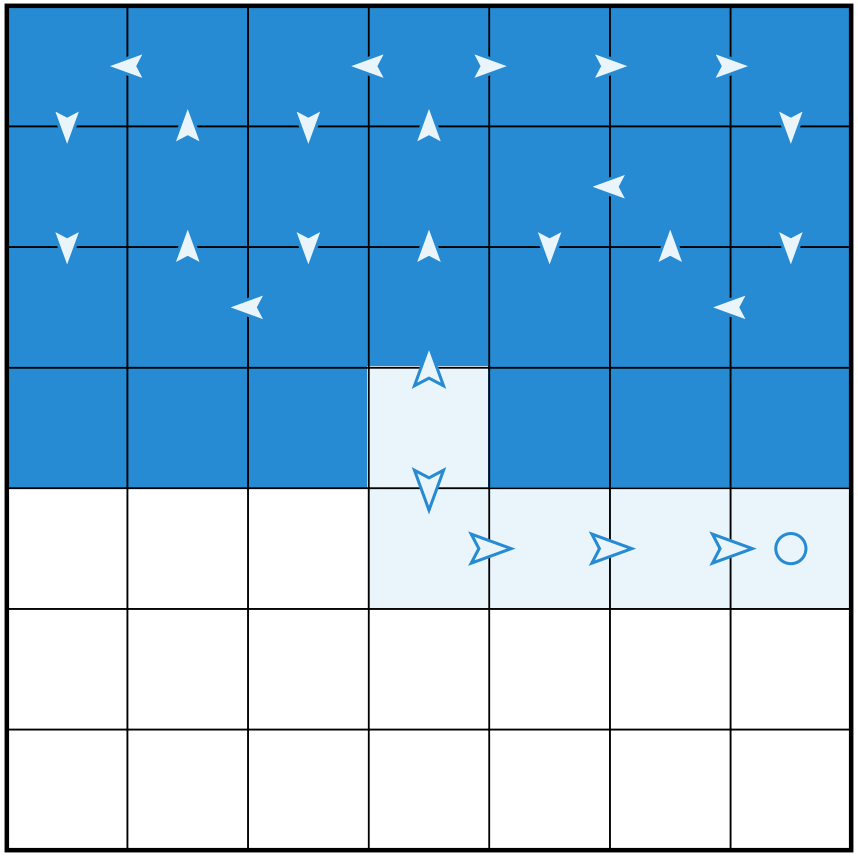

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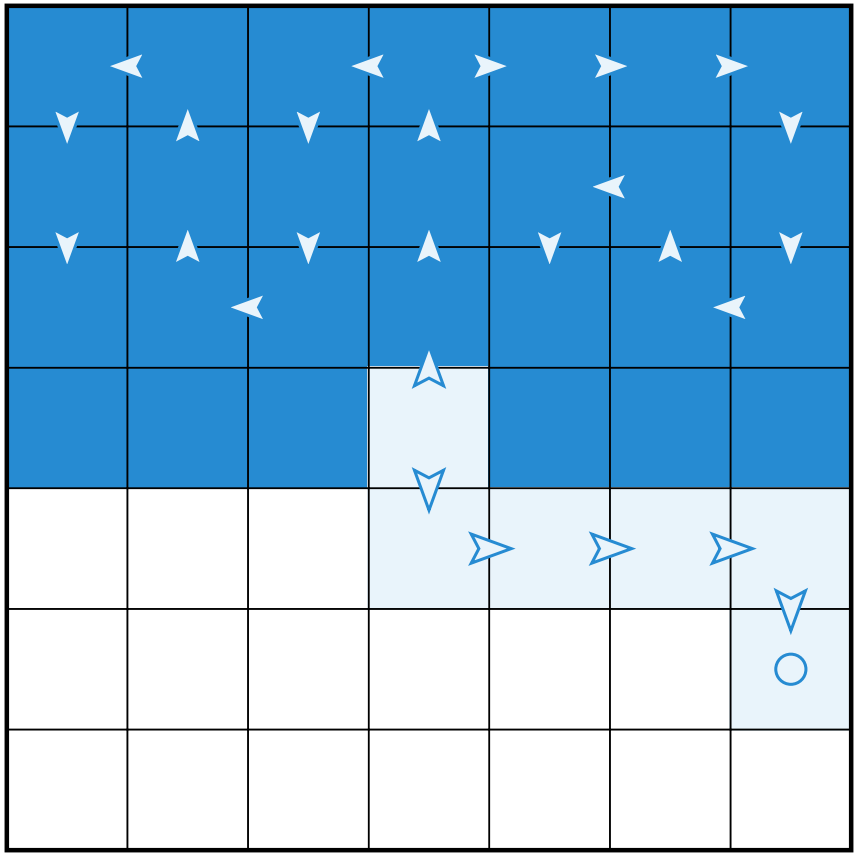

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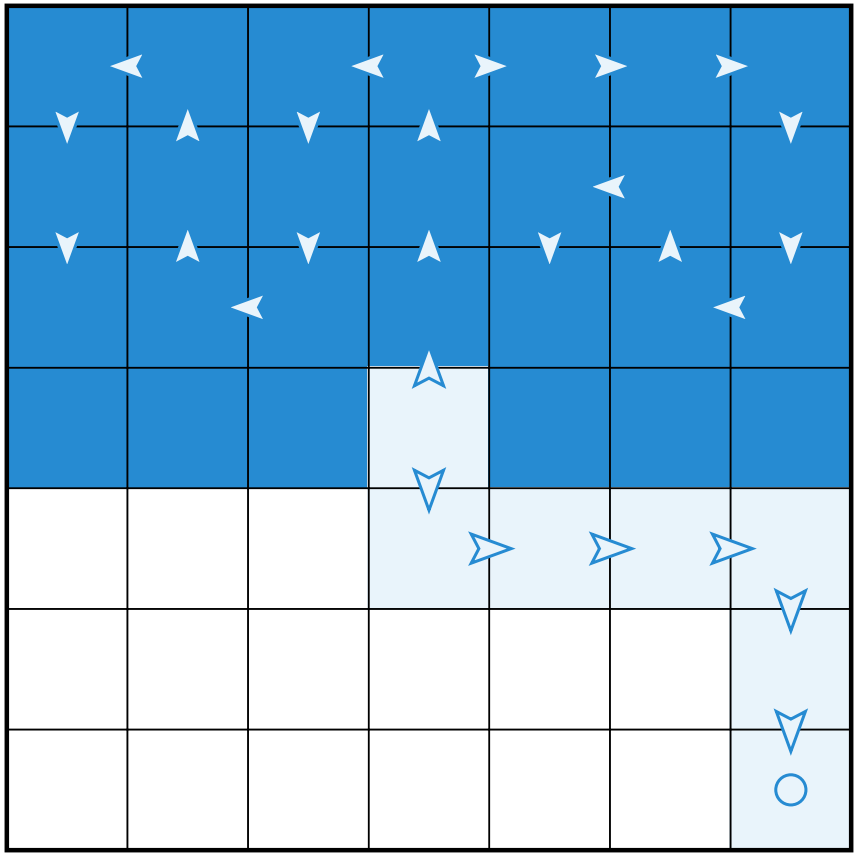

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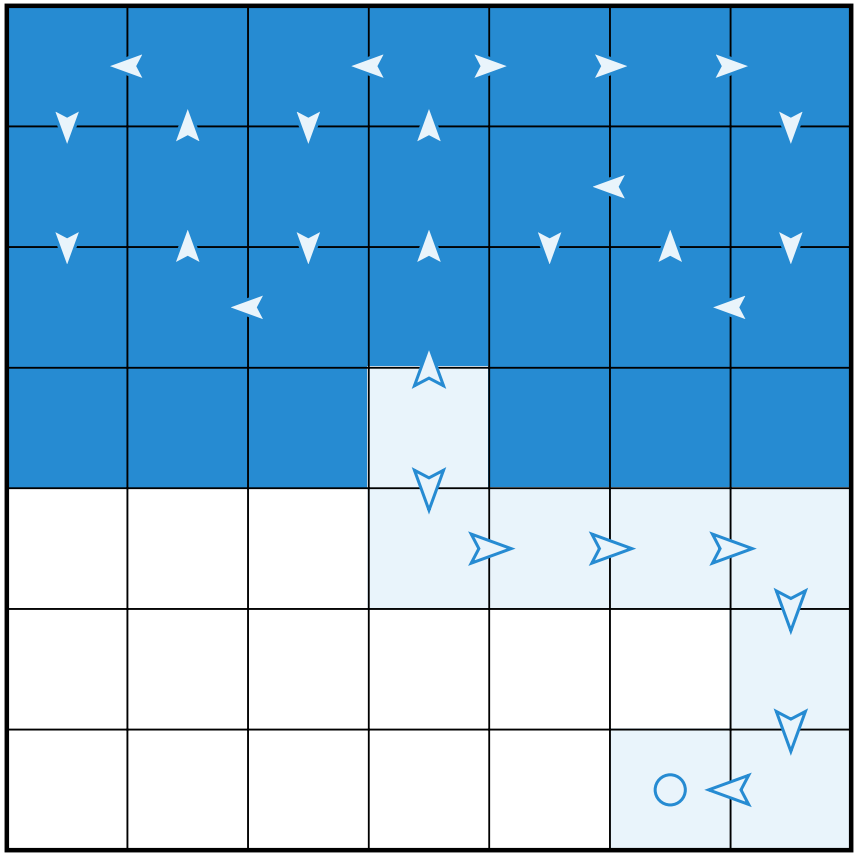

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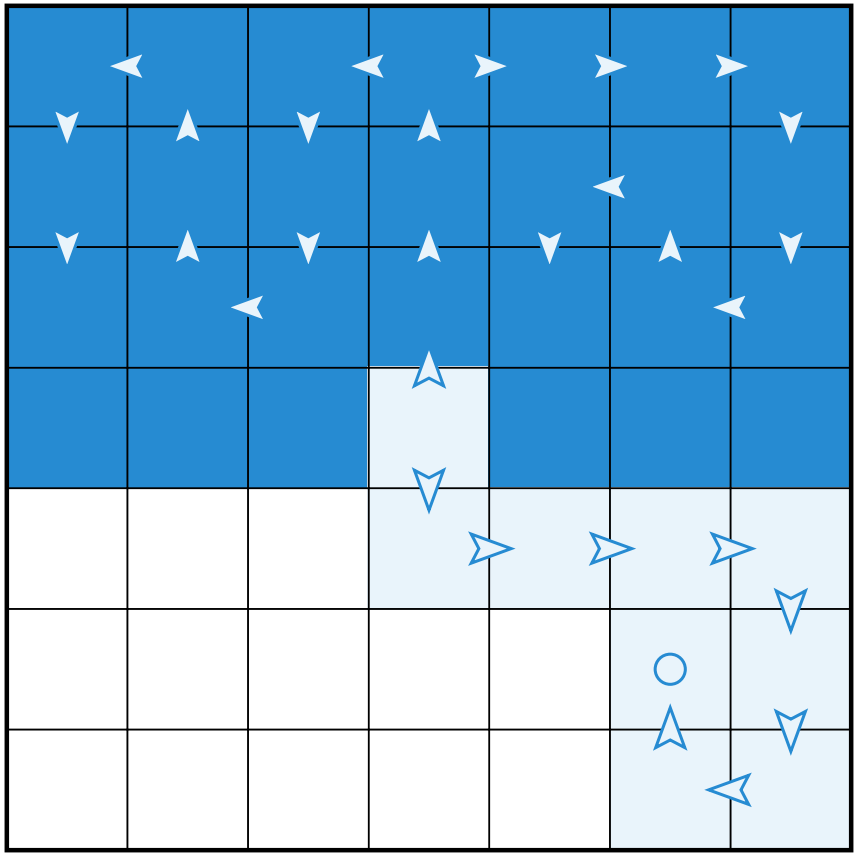

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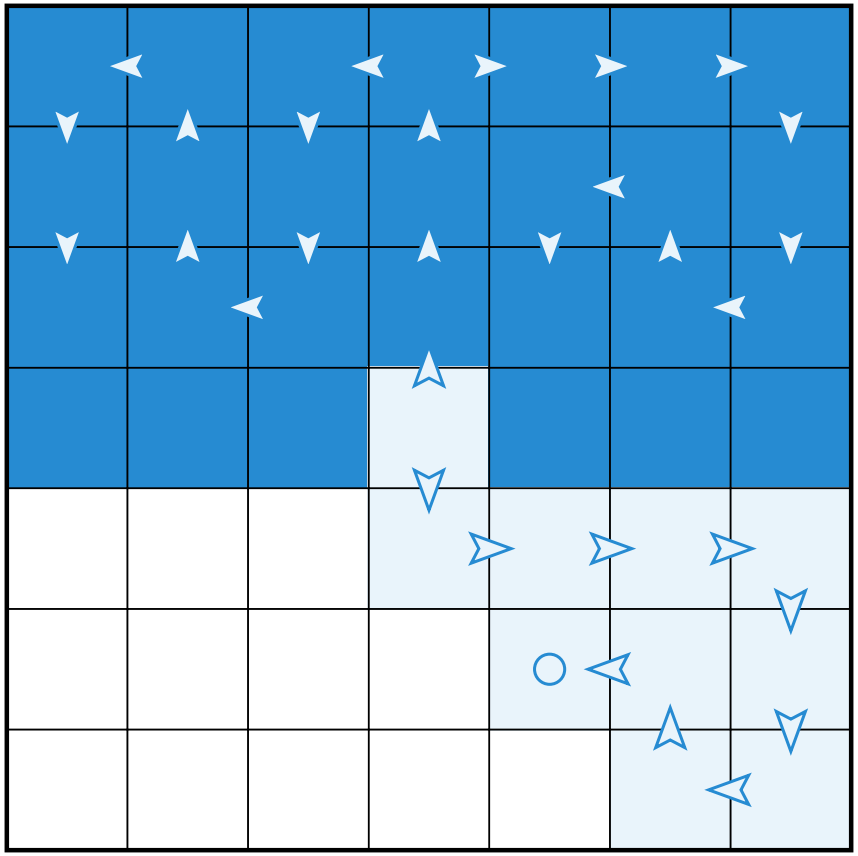

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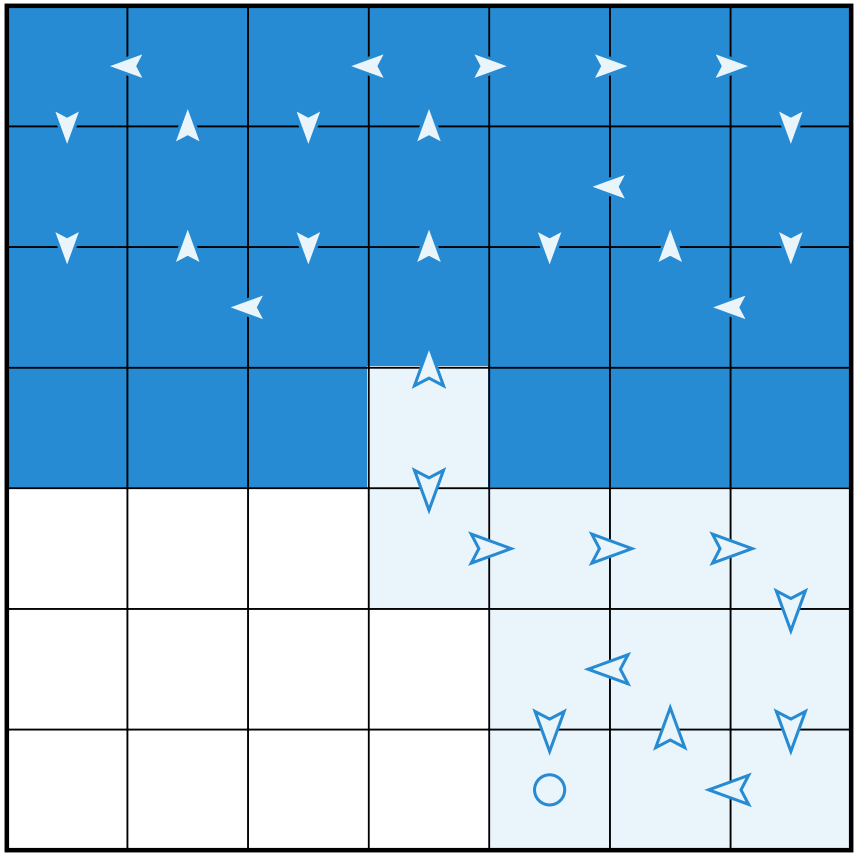

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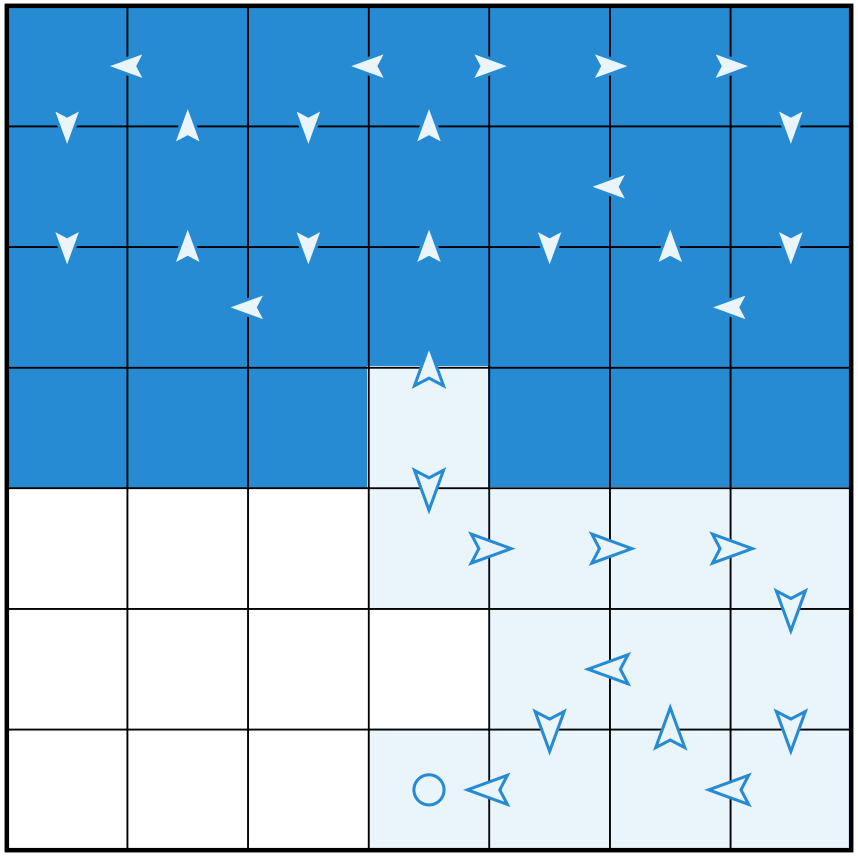

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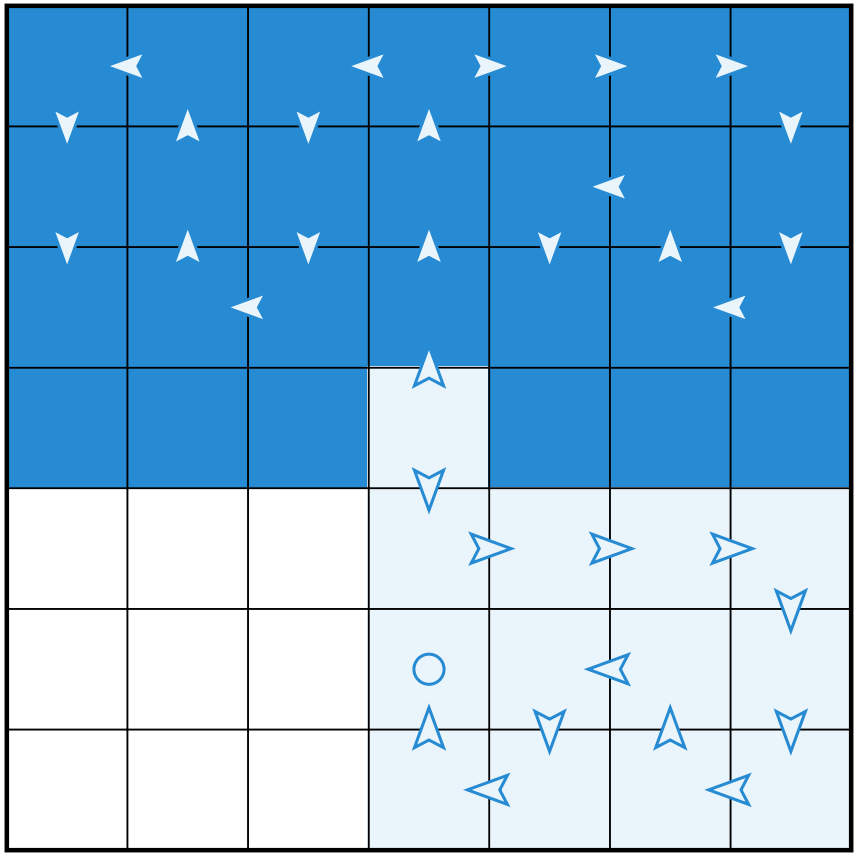
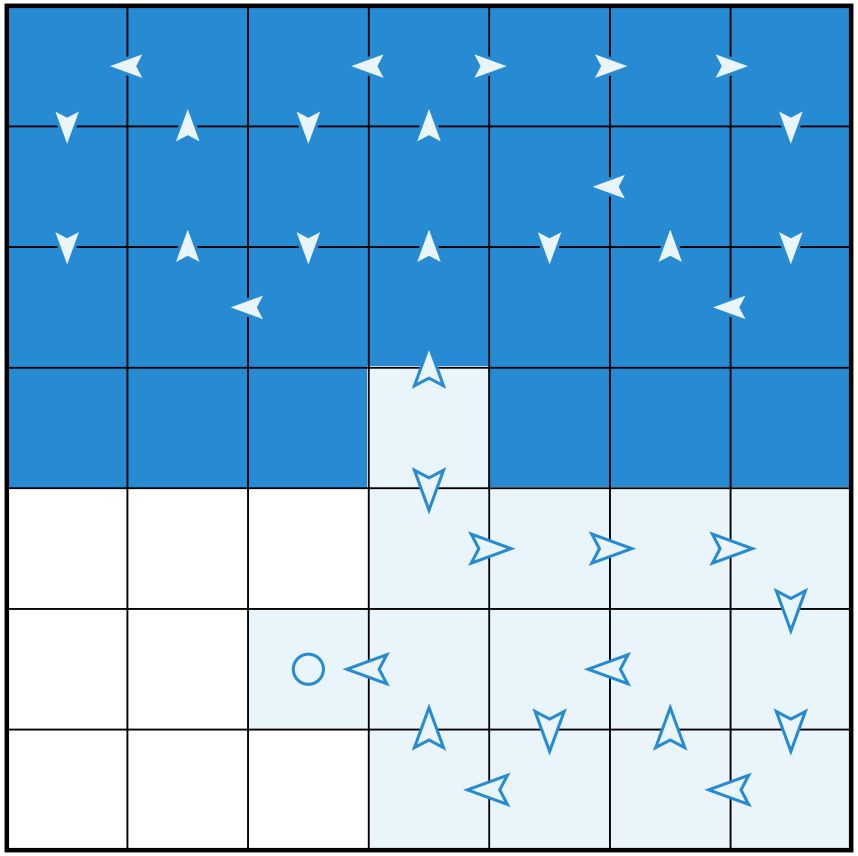
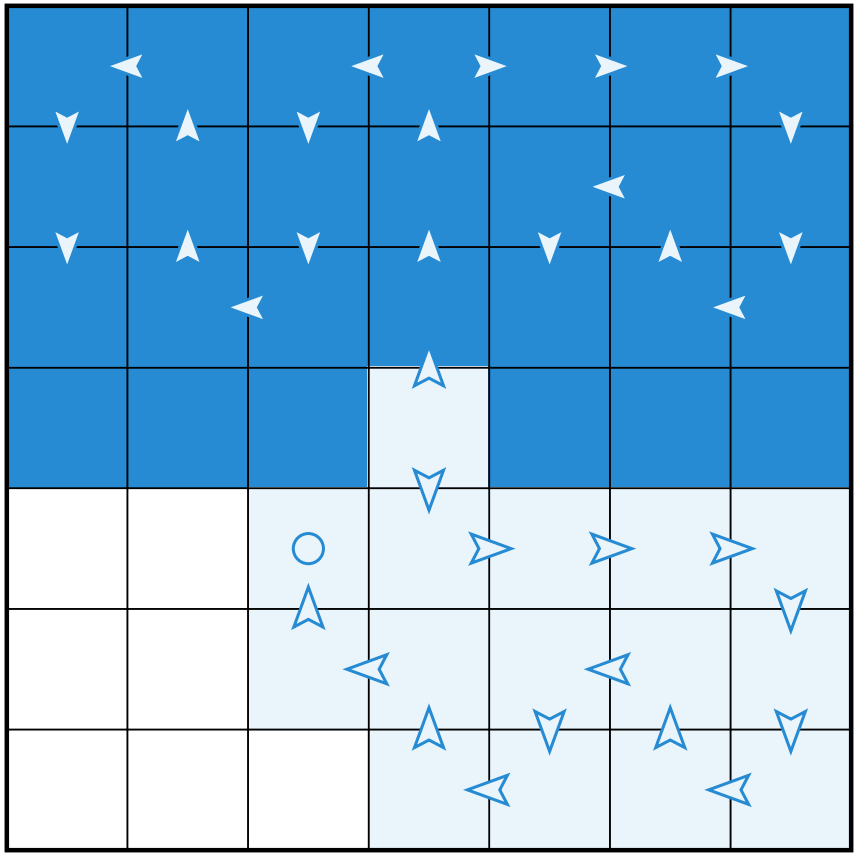


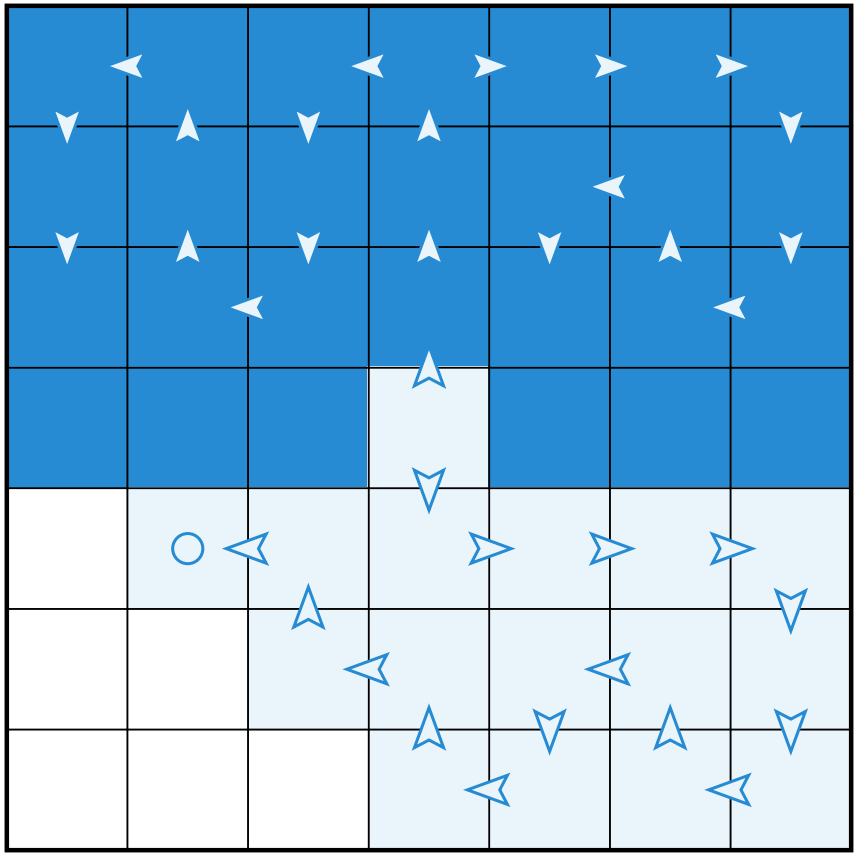
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



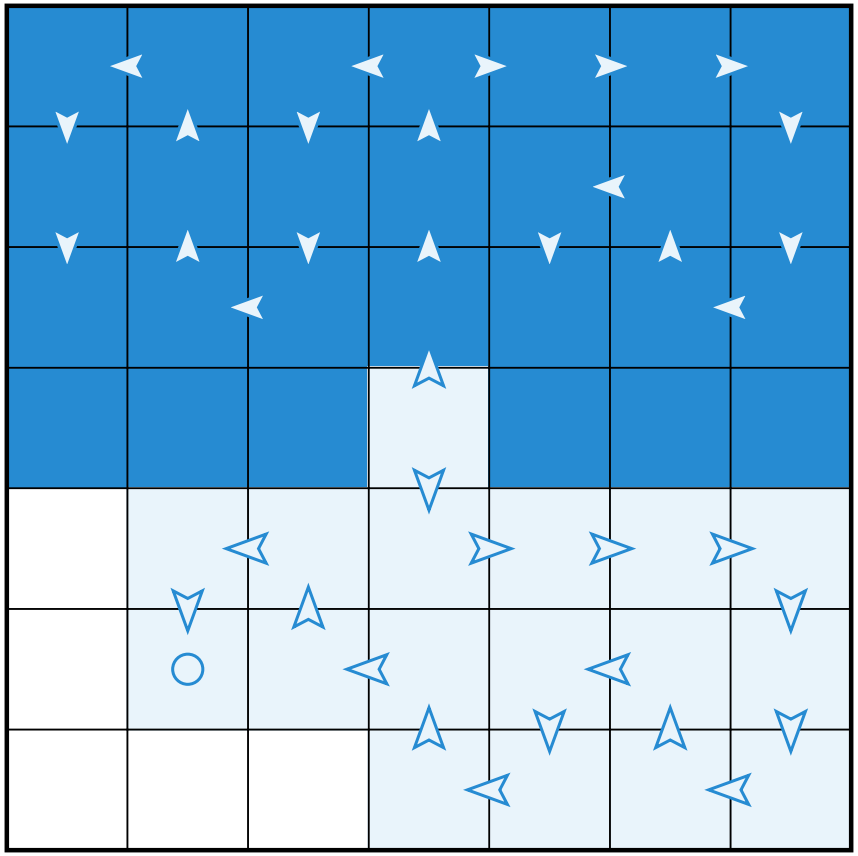
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



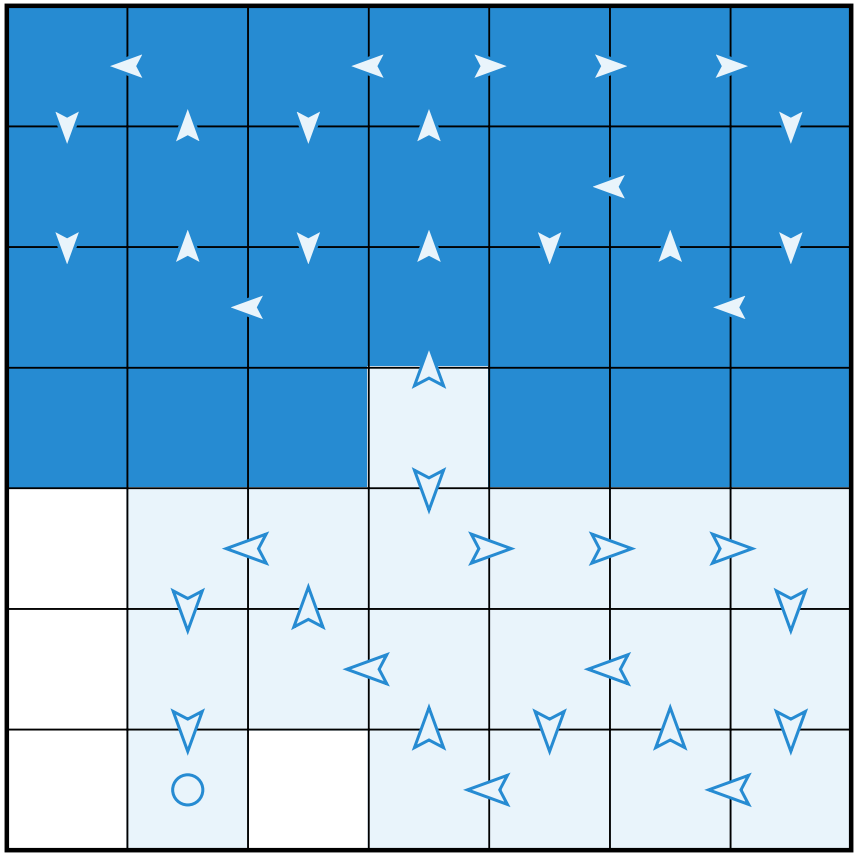
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



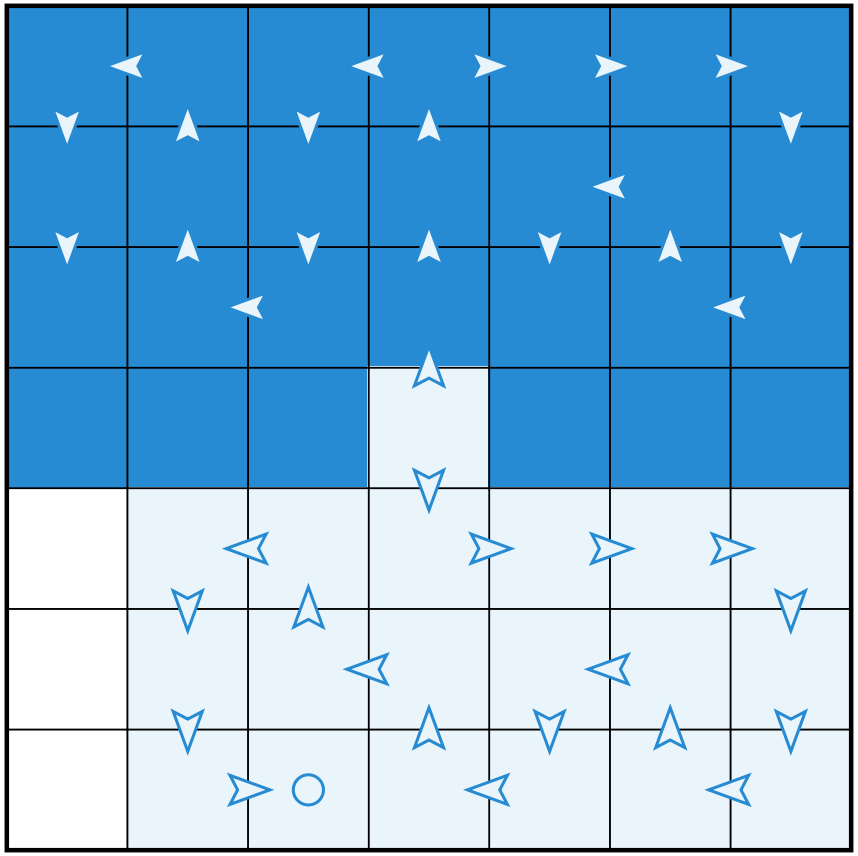
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



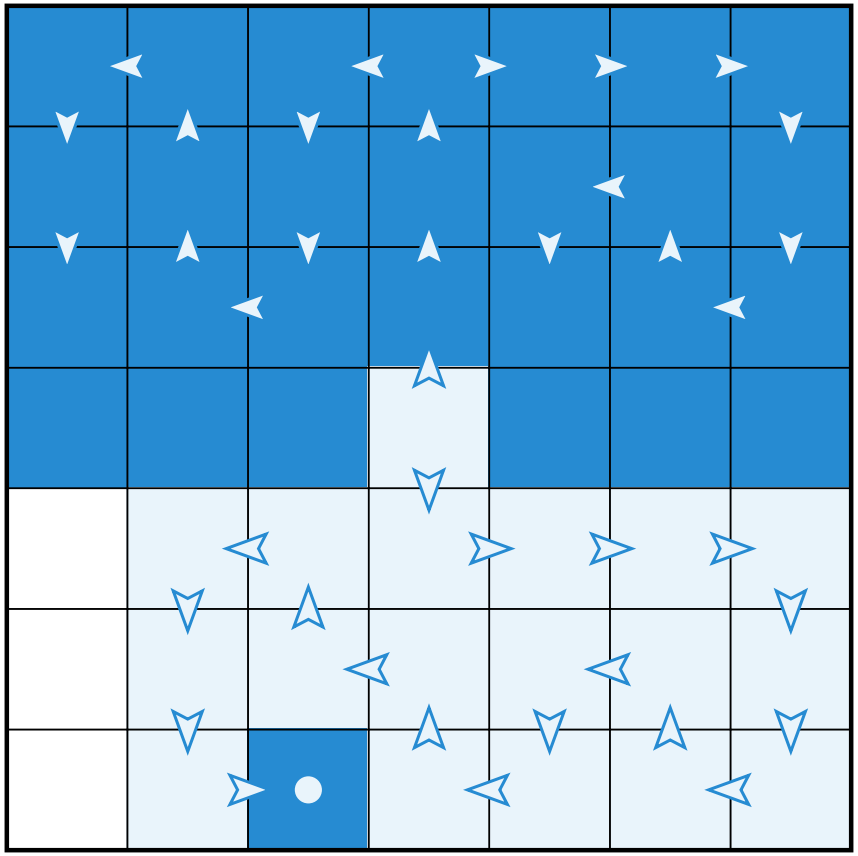
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



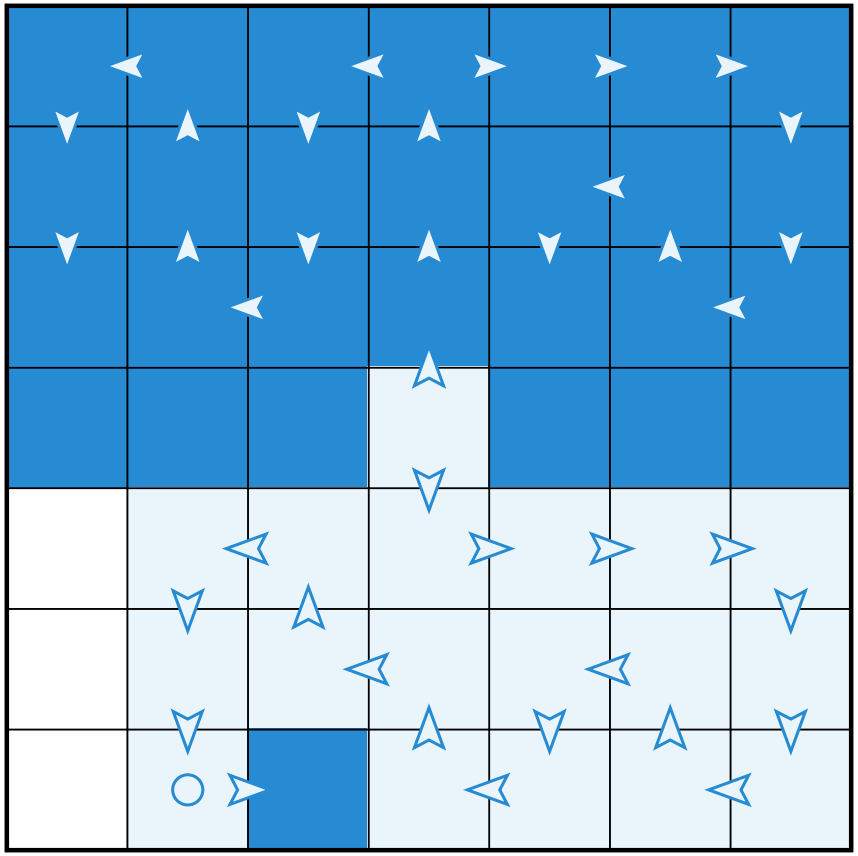
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



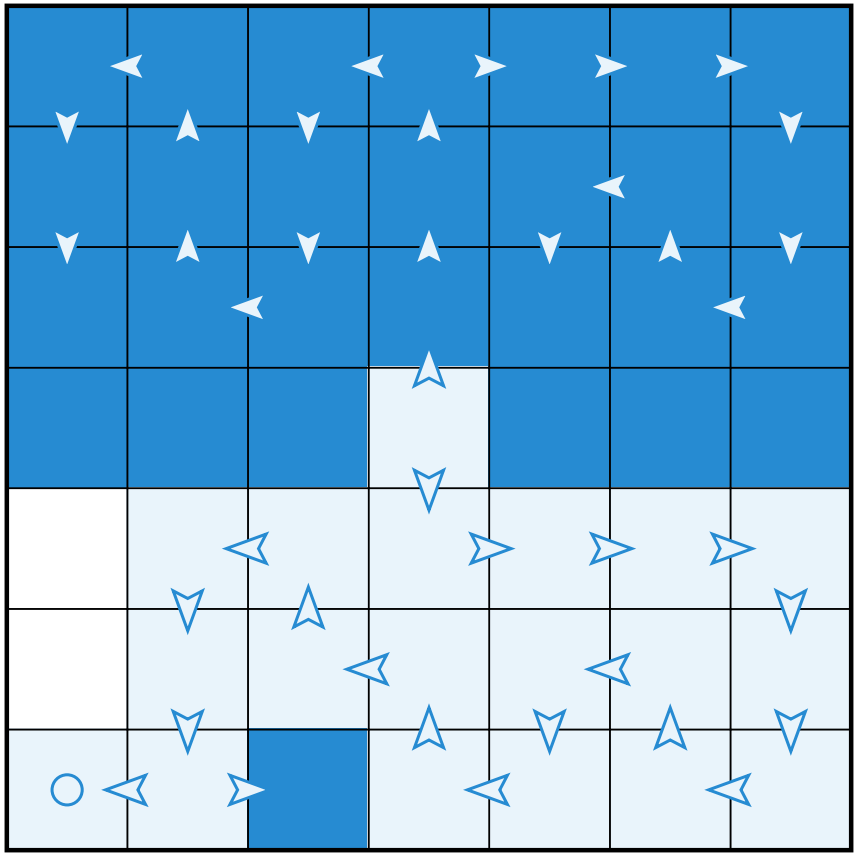
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



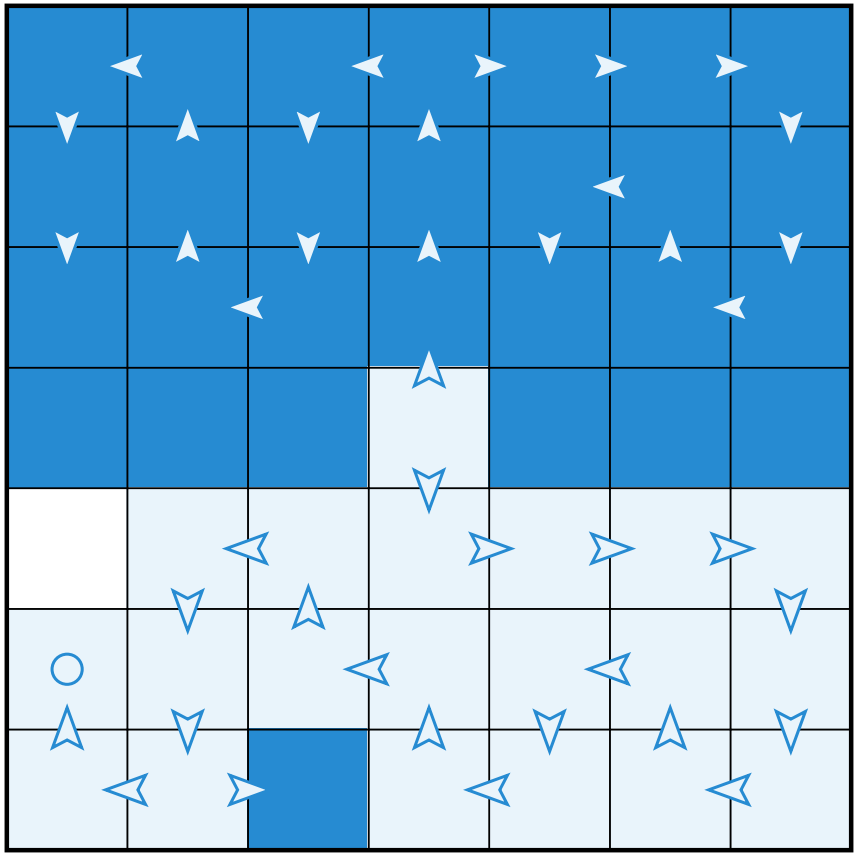
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



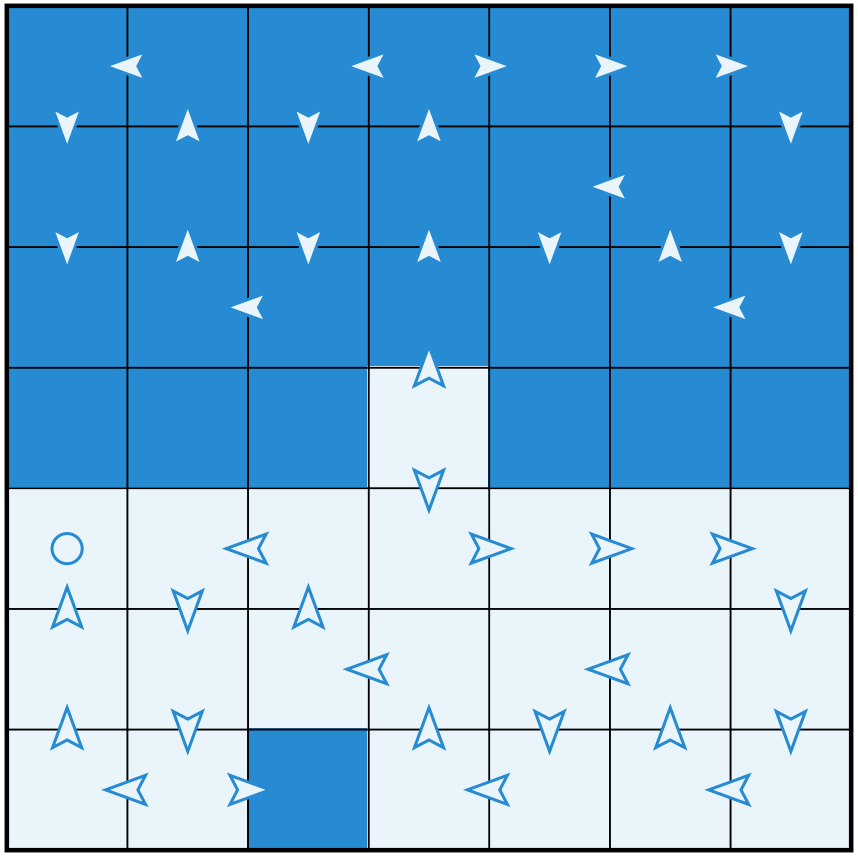
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



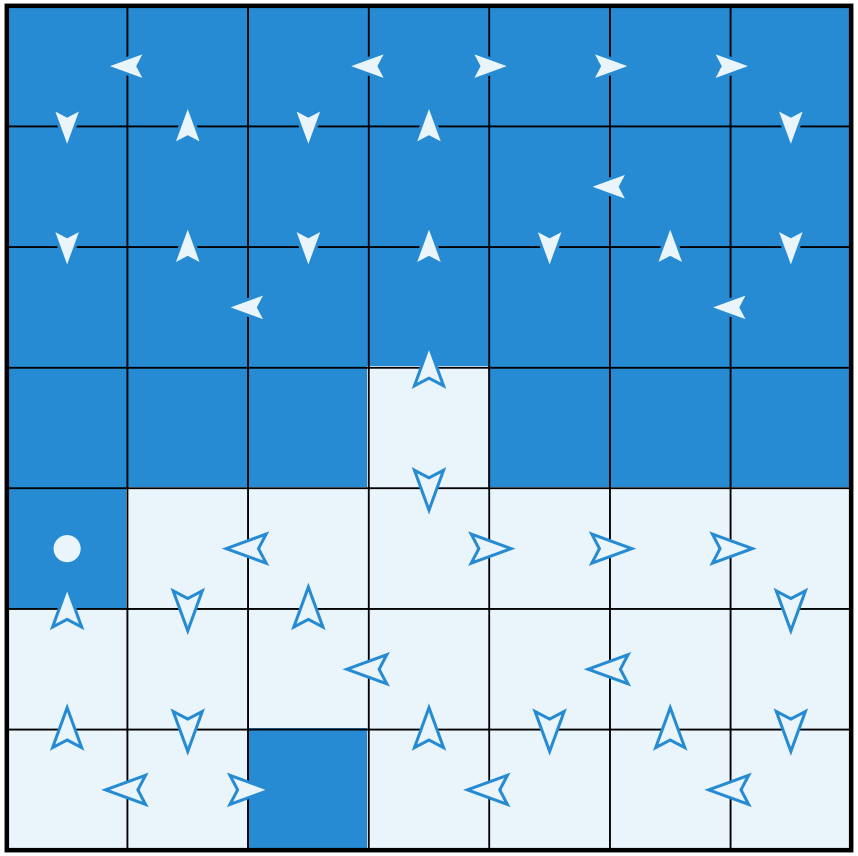
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



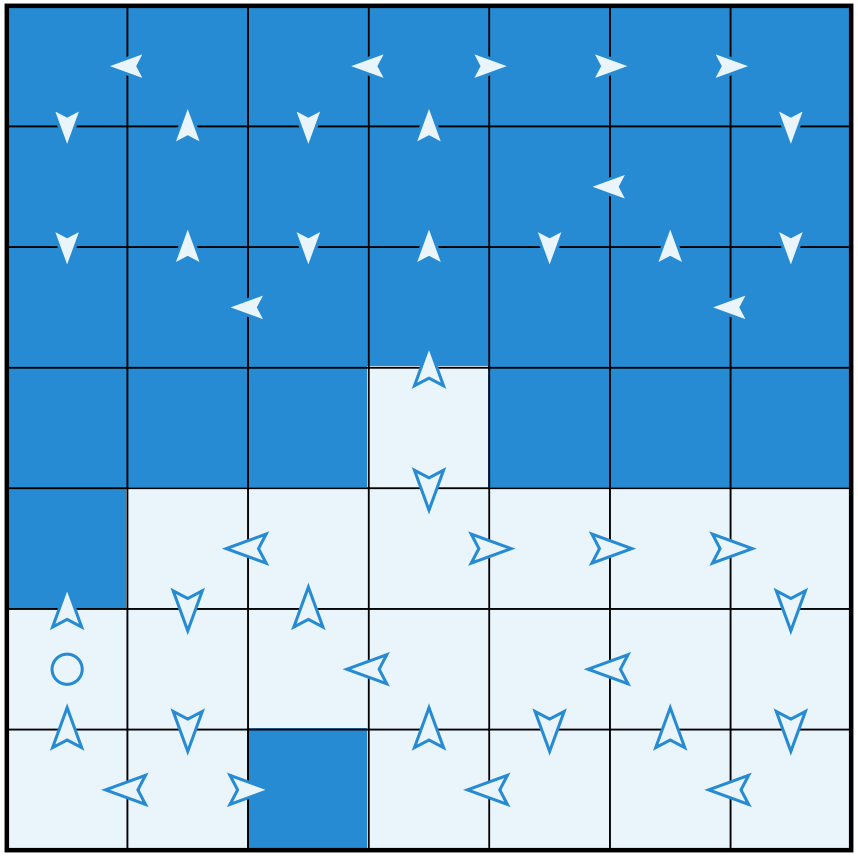
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



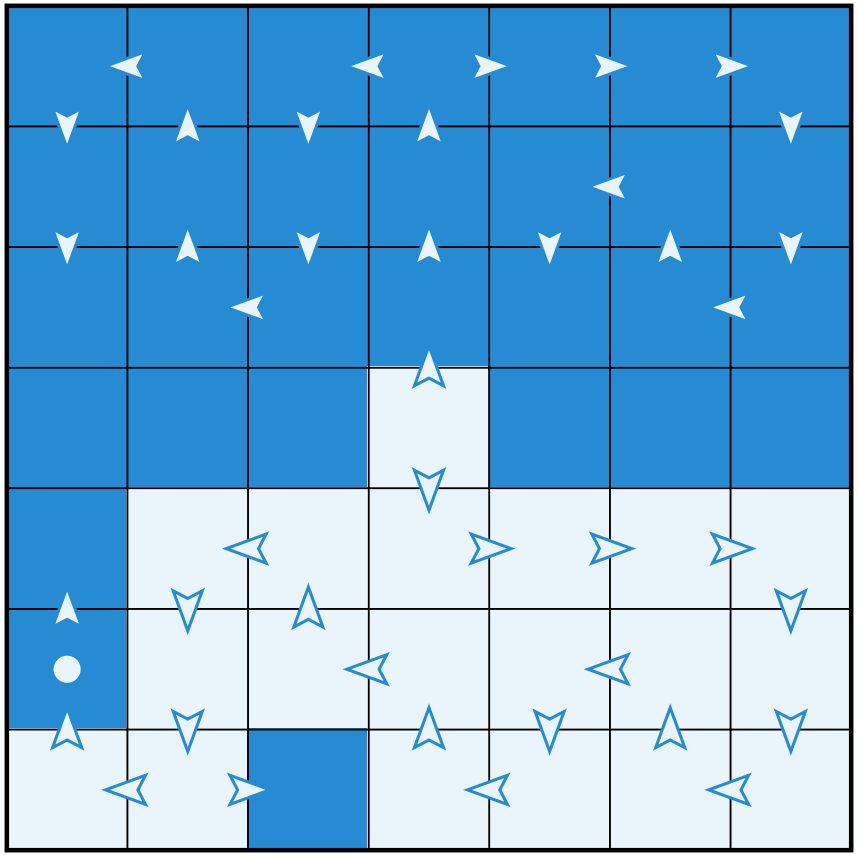
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



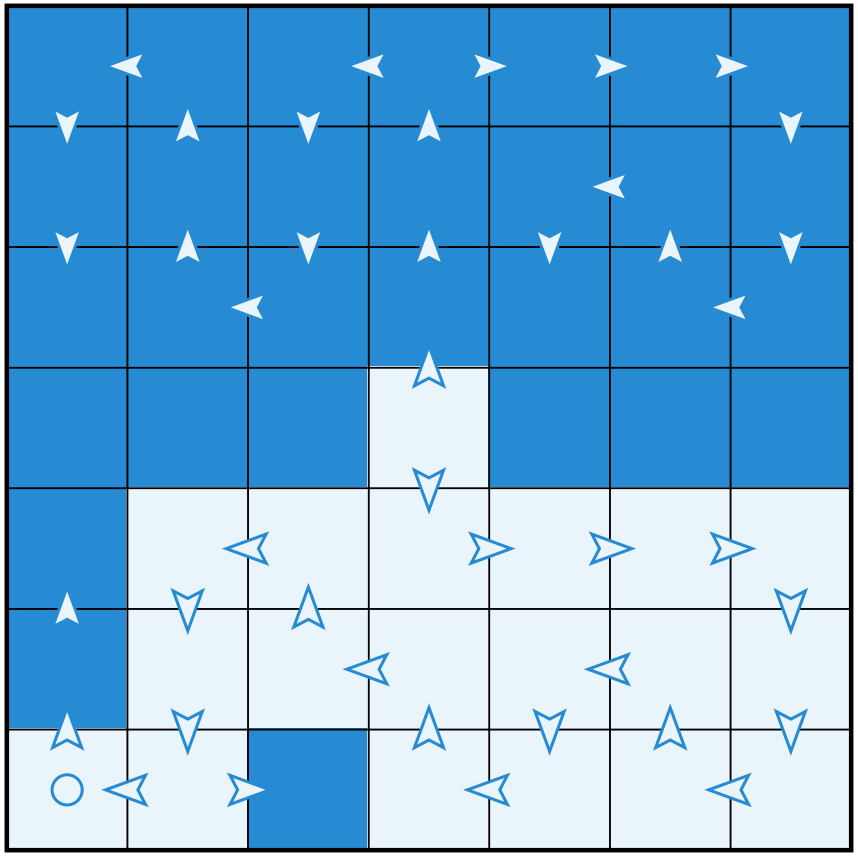
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



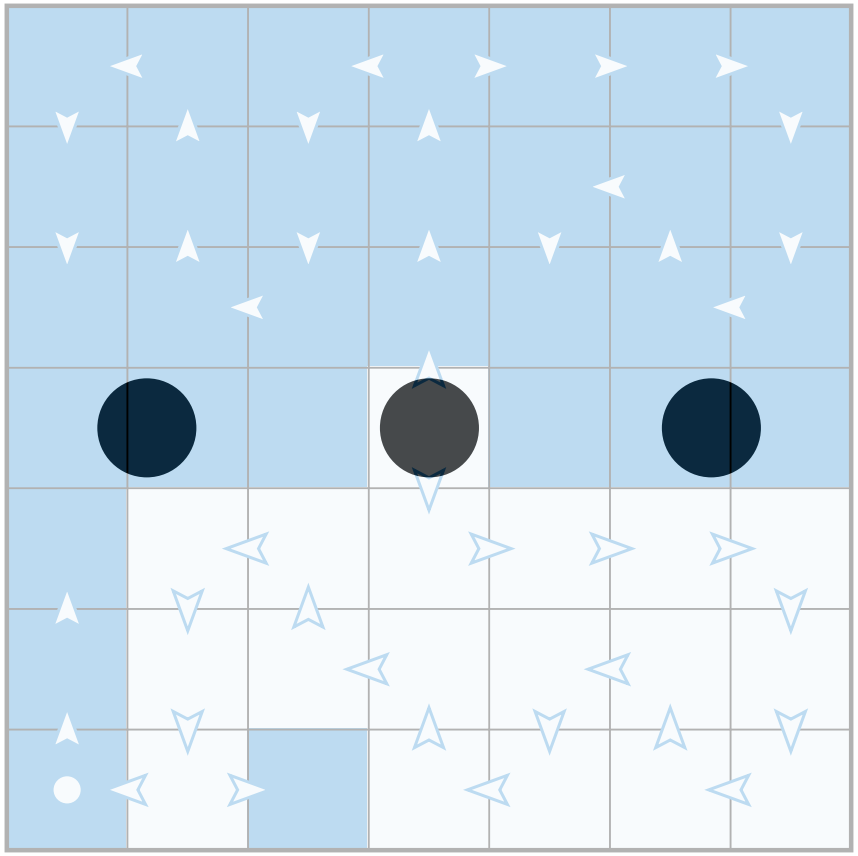
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



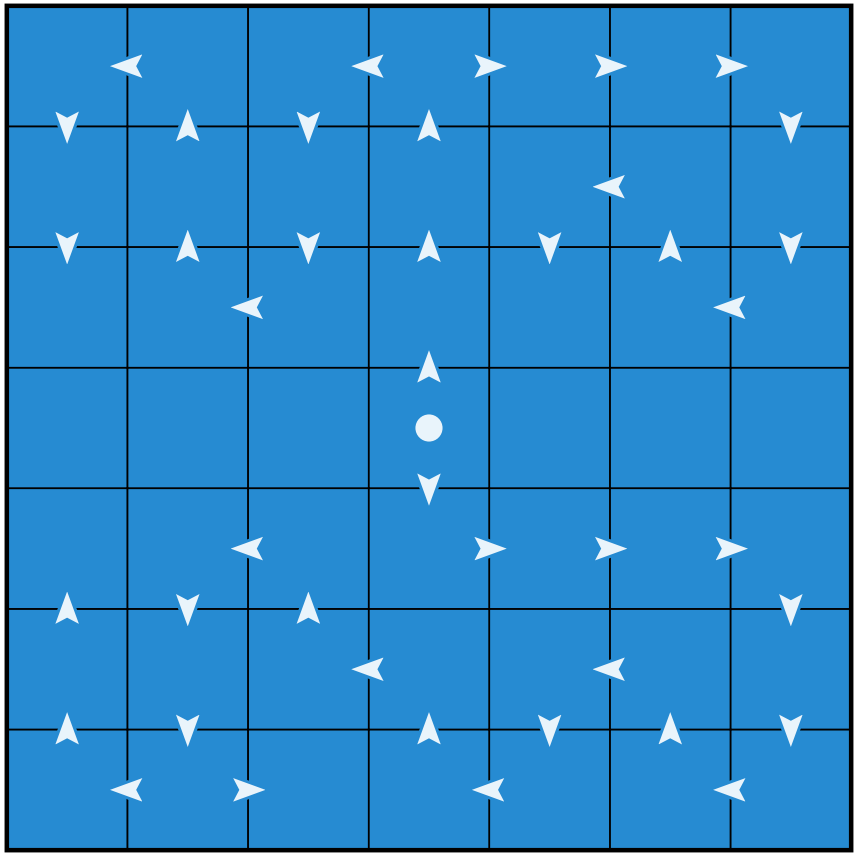
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



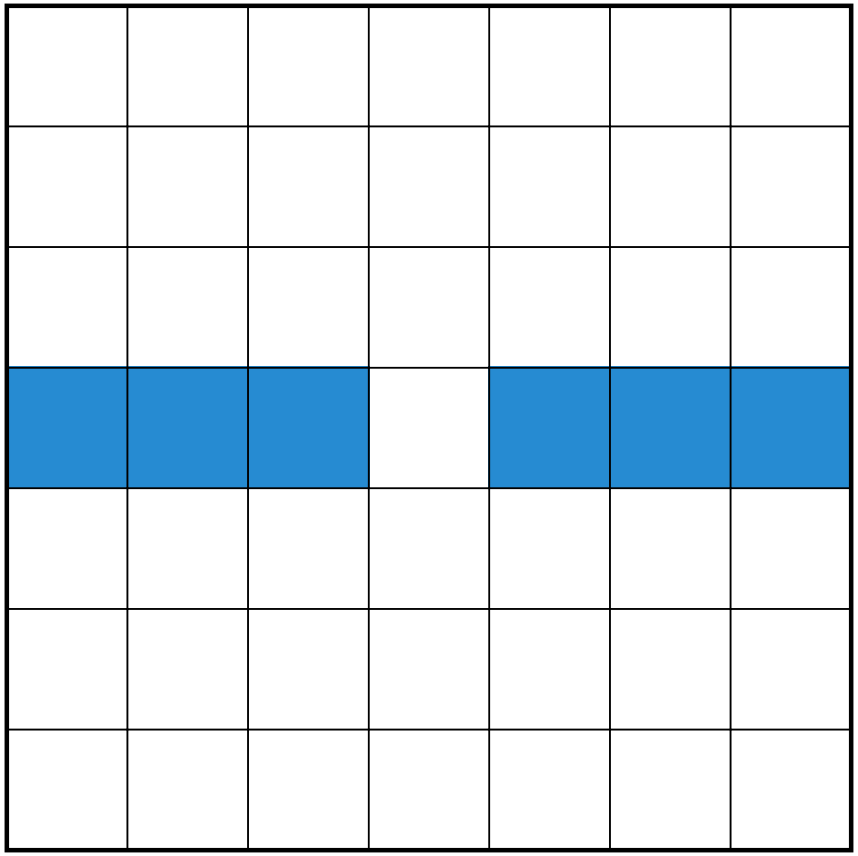
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest



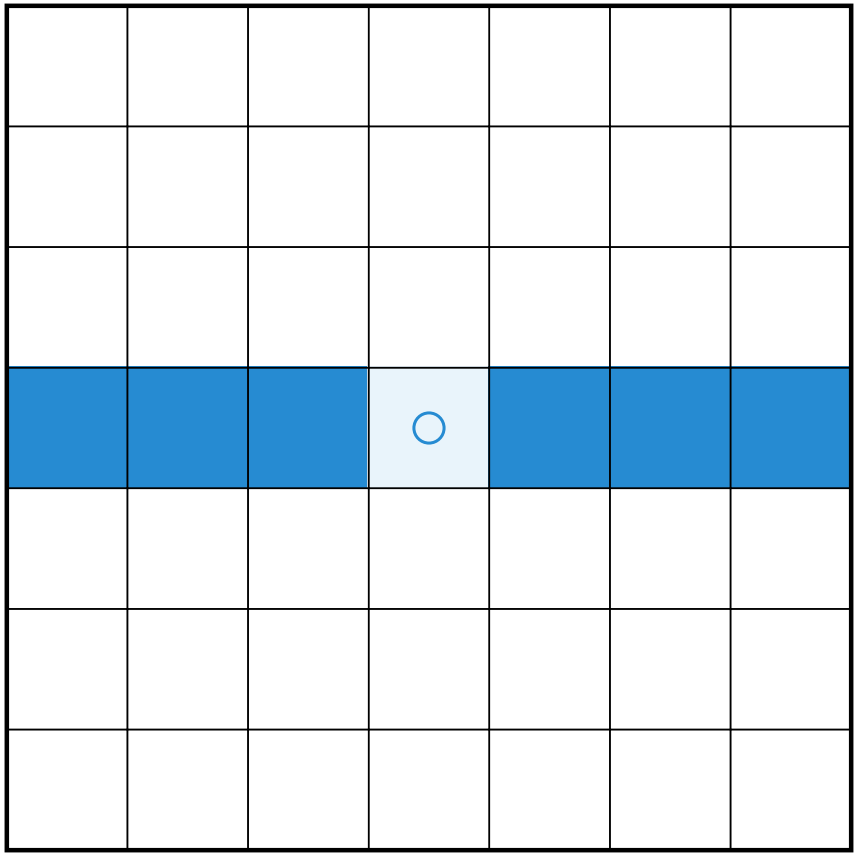
DFS, *flood-fill*: Fyll rekursivt nord, øst, sør, vest

Flood-fill 2

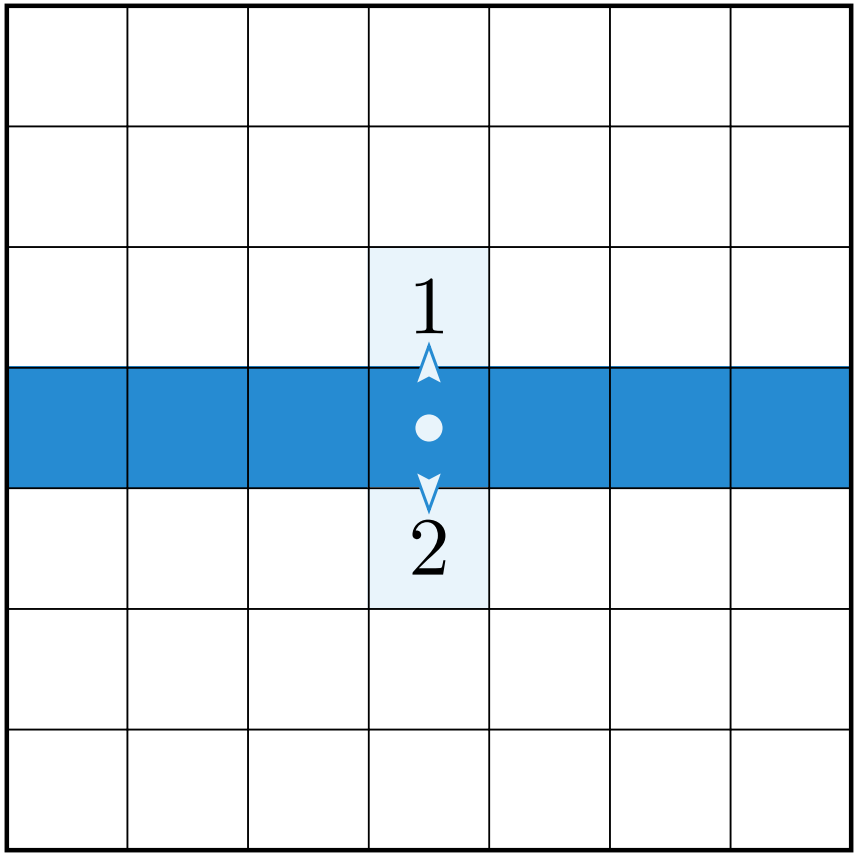
BFS-versjon



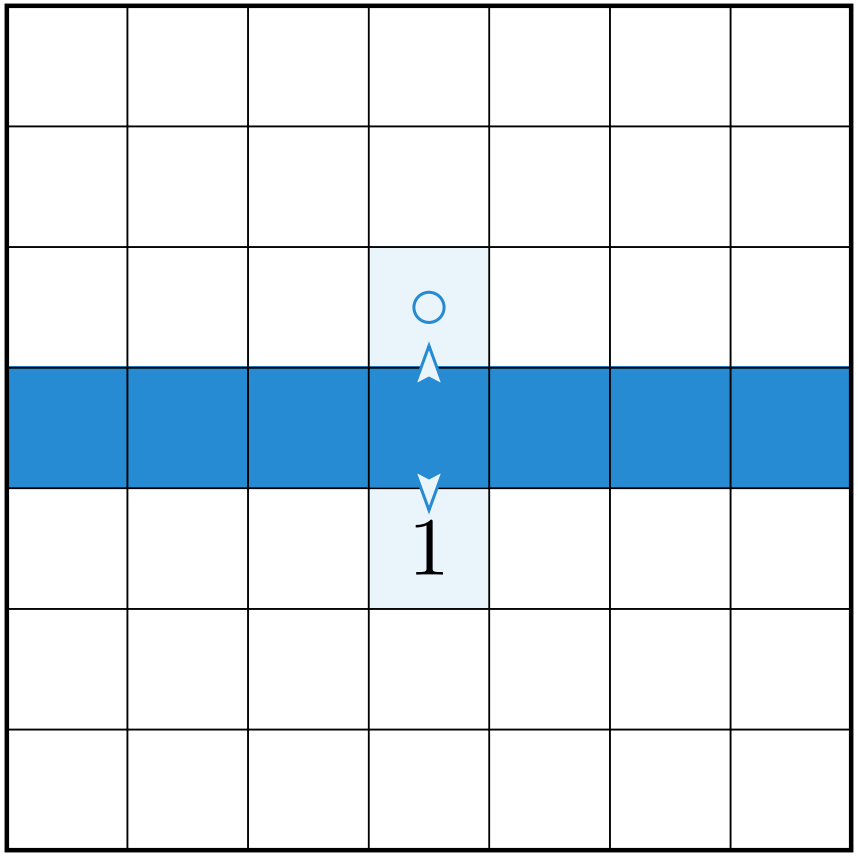
BFS: Naboer stiller seg i kø



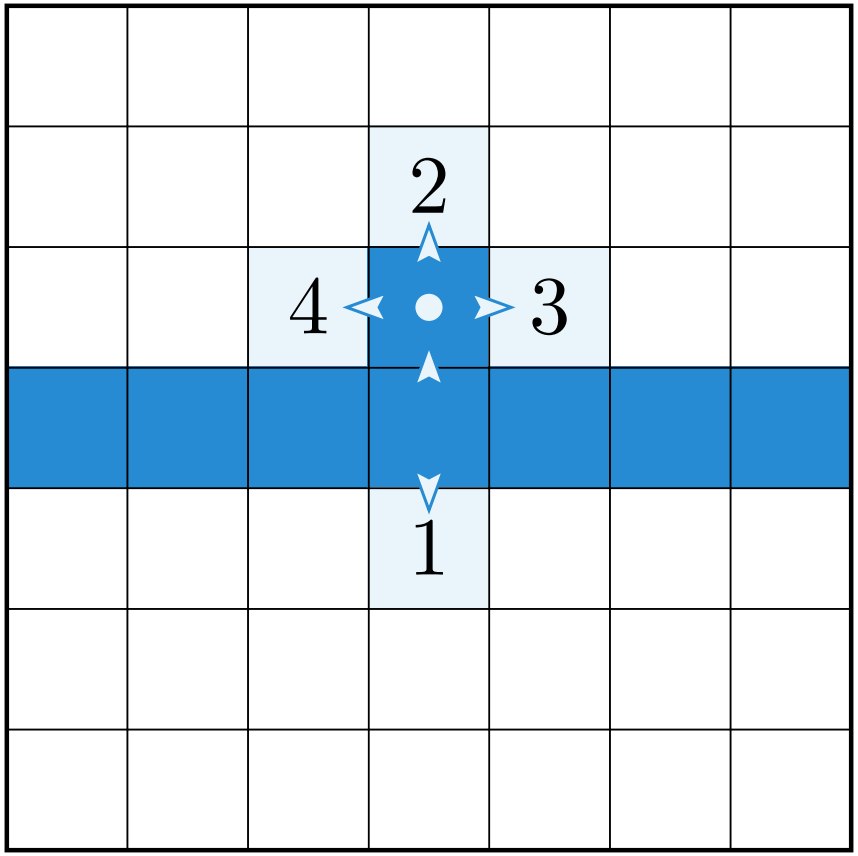
BFS: Naboer stiller seg i kø



BFS: Naboer stiller seg i kø



BFS: Naboer stiller seg i kø



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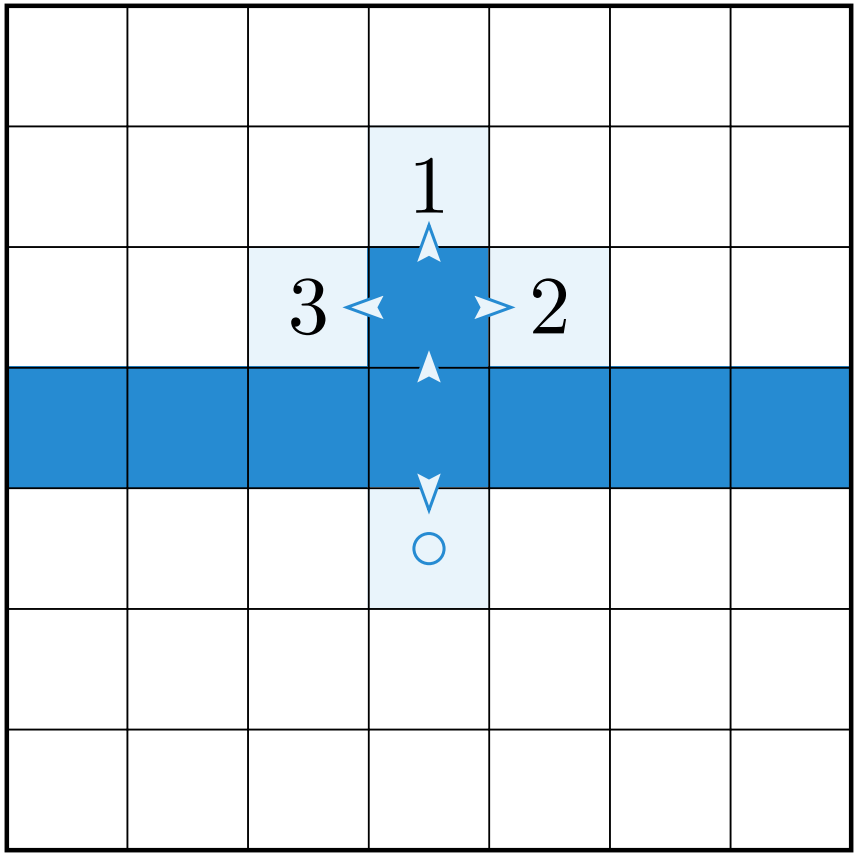
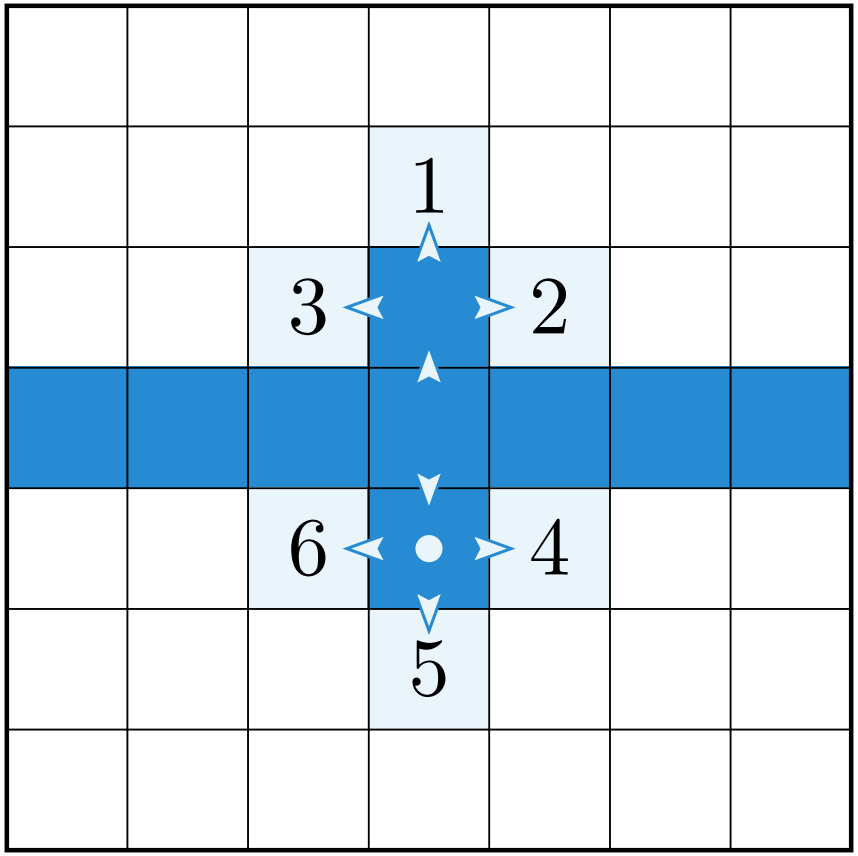
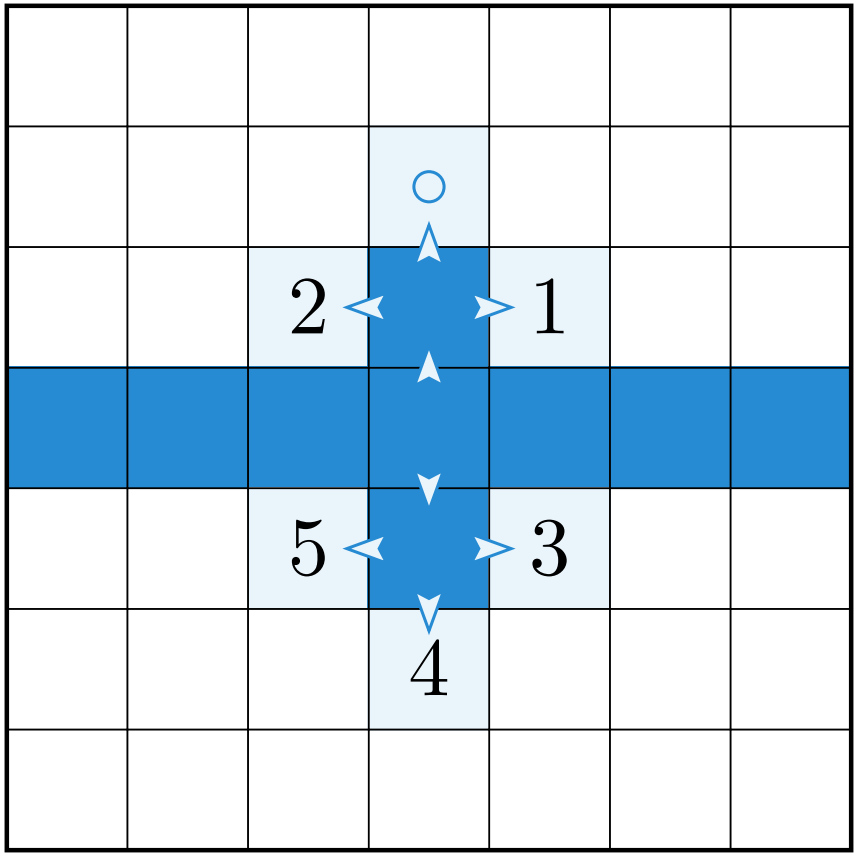


BFS: Naboer stiller seg i kø



BFS: Naboer stiller seg i kø



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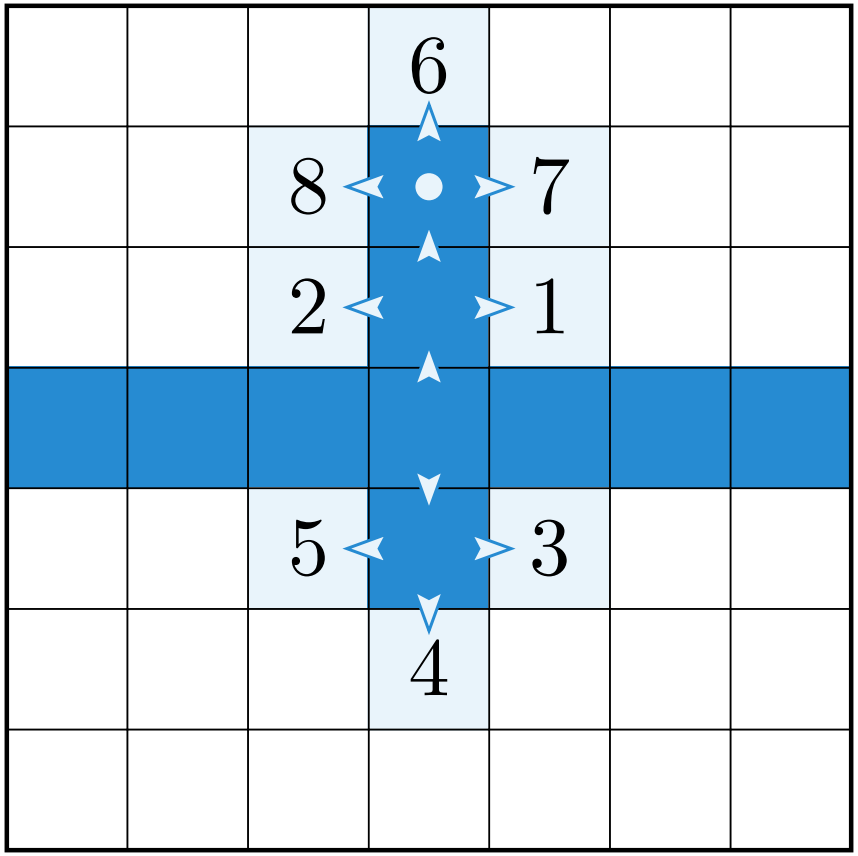

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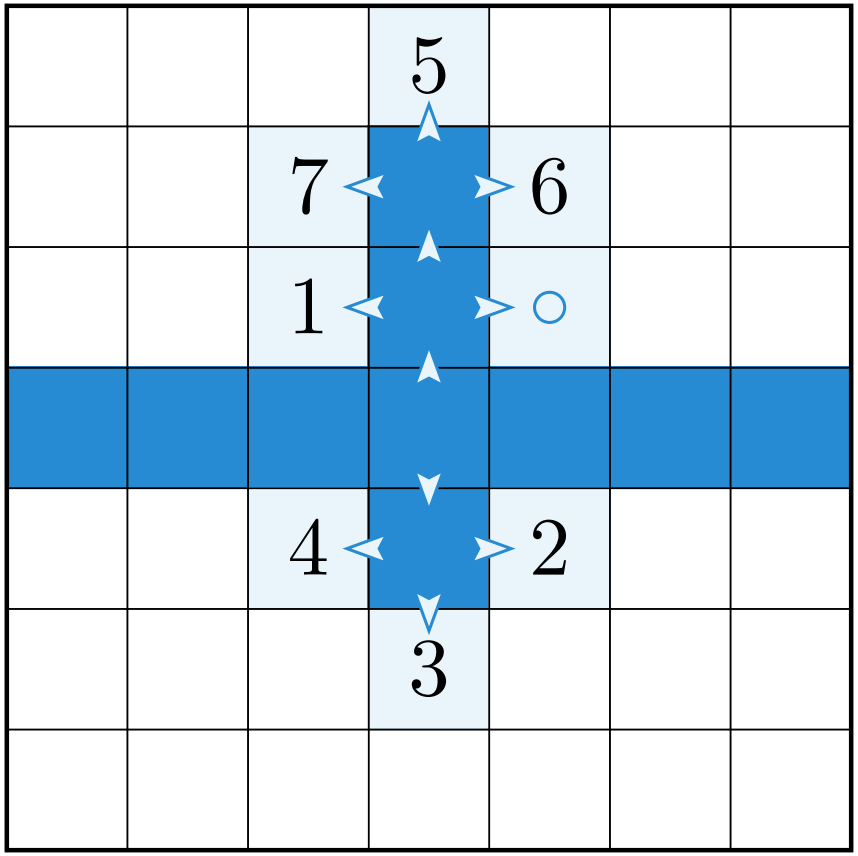

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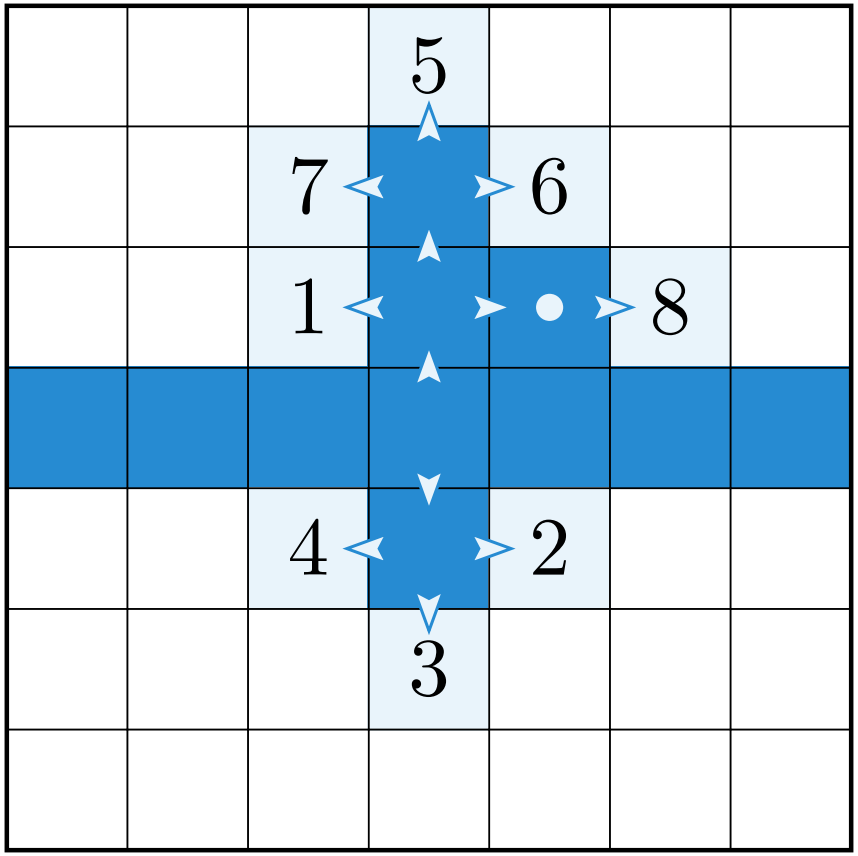

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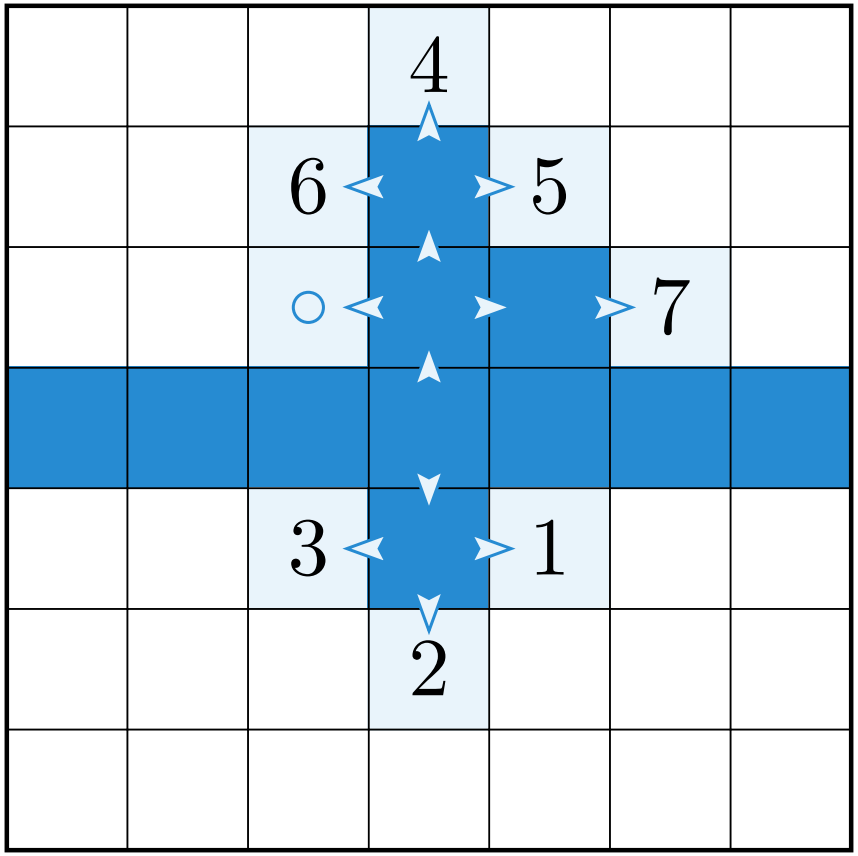

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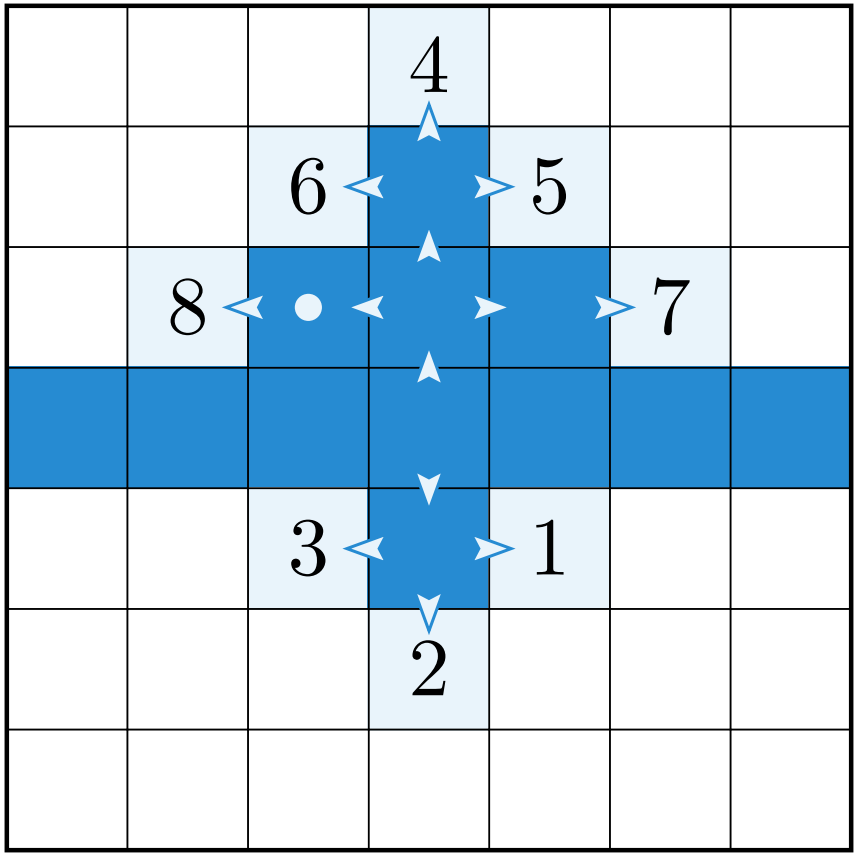

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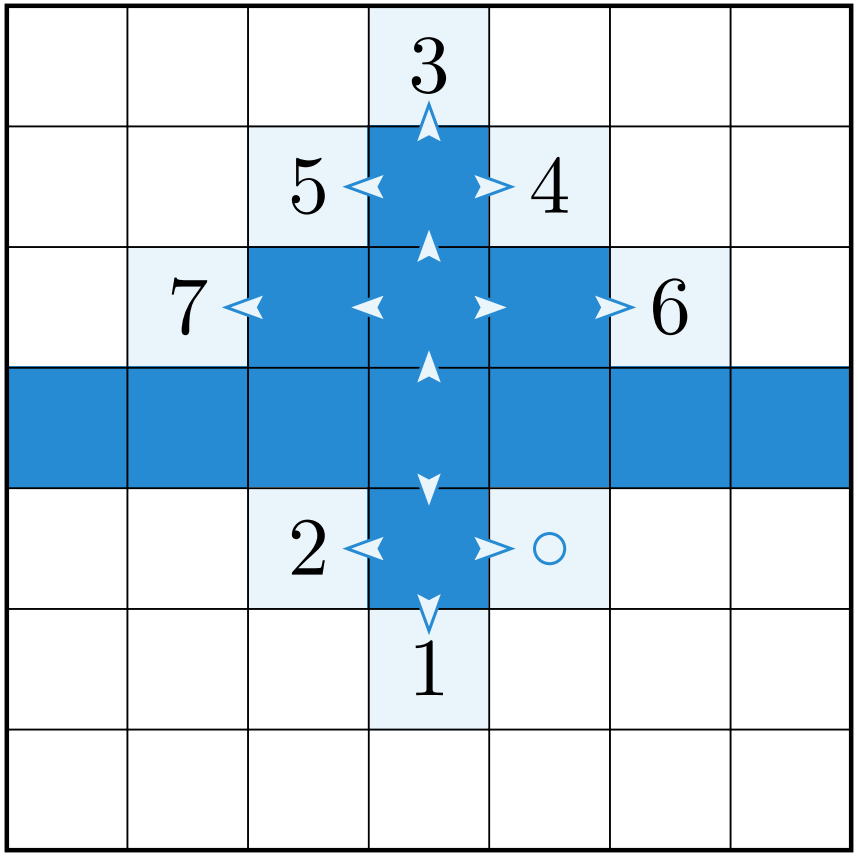

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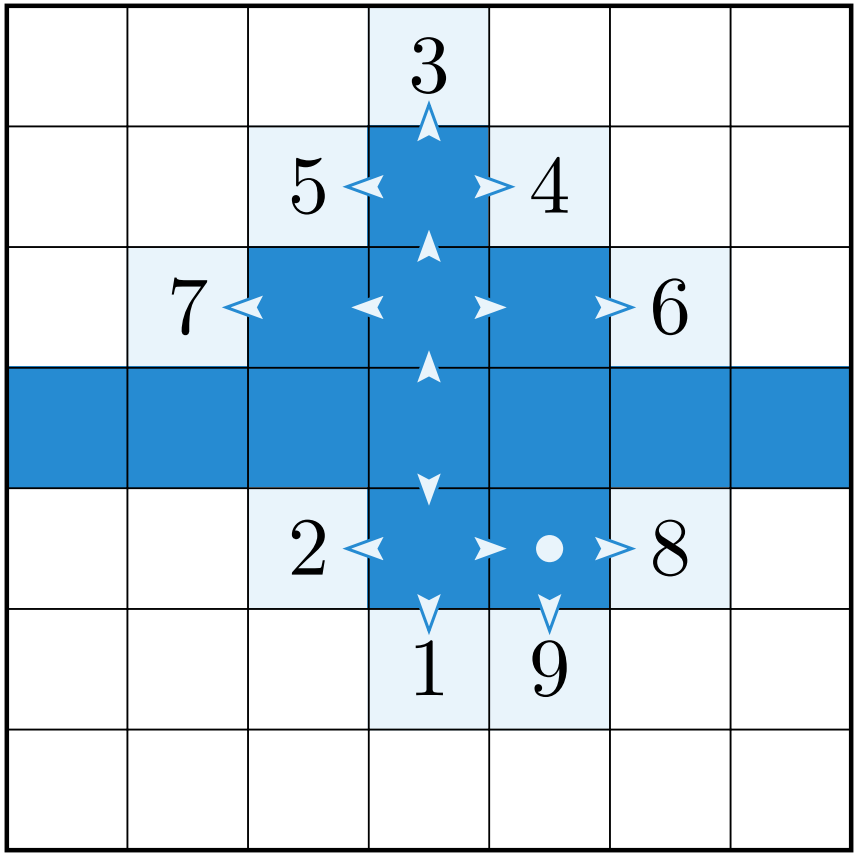
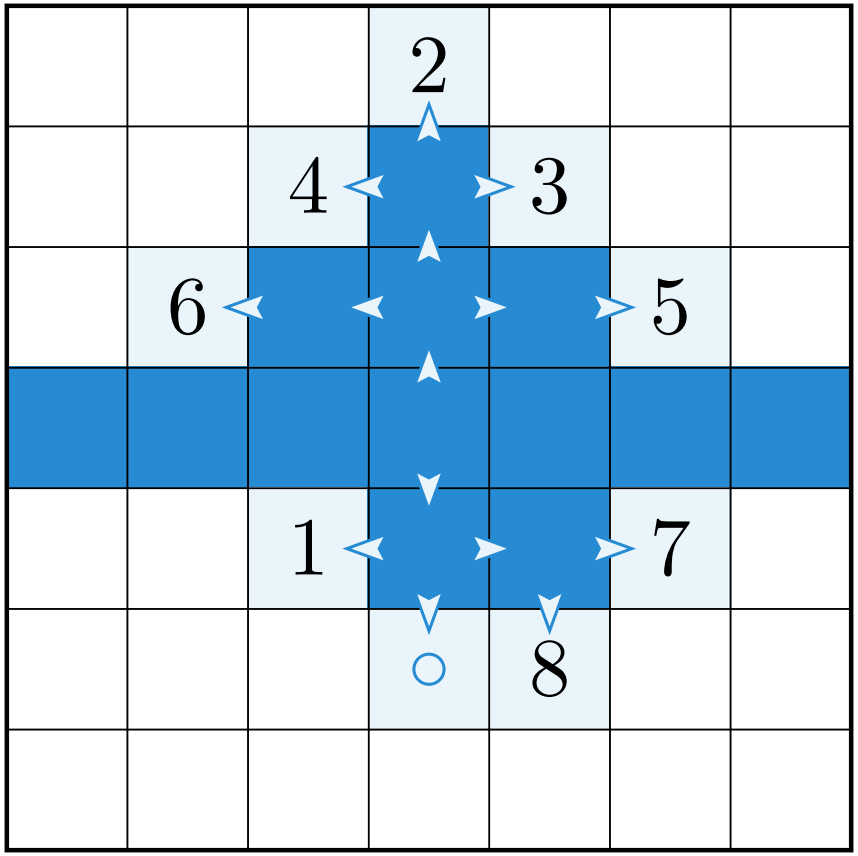
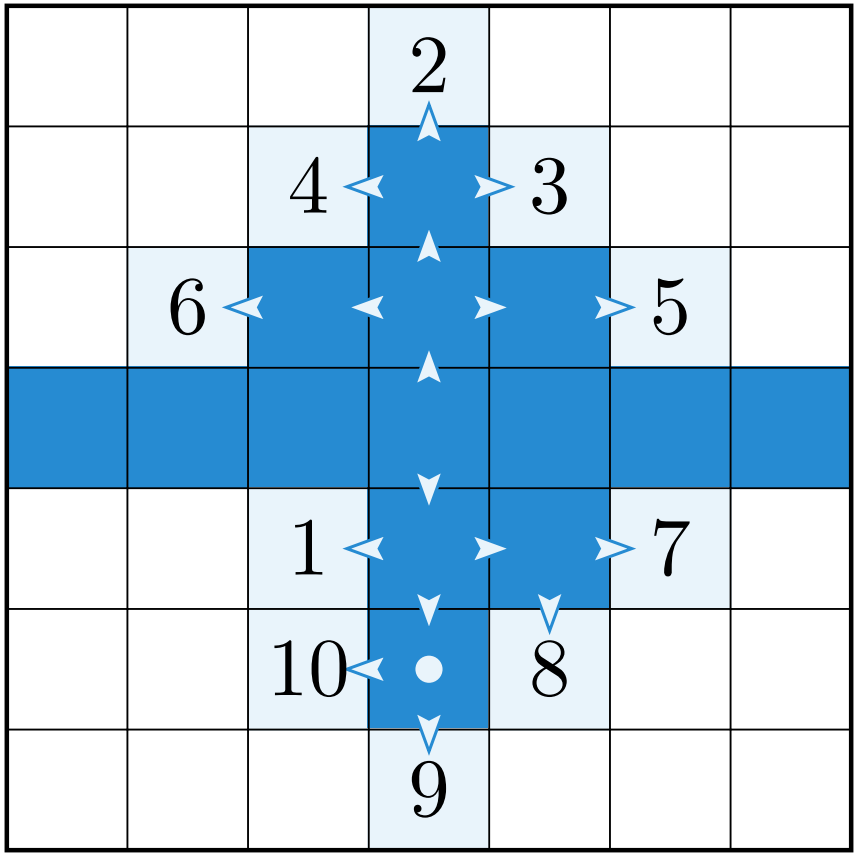


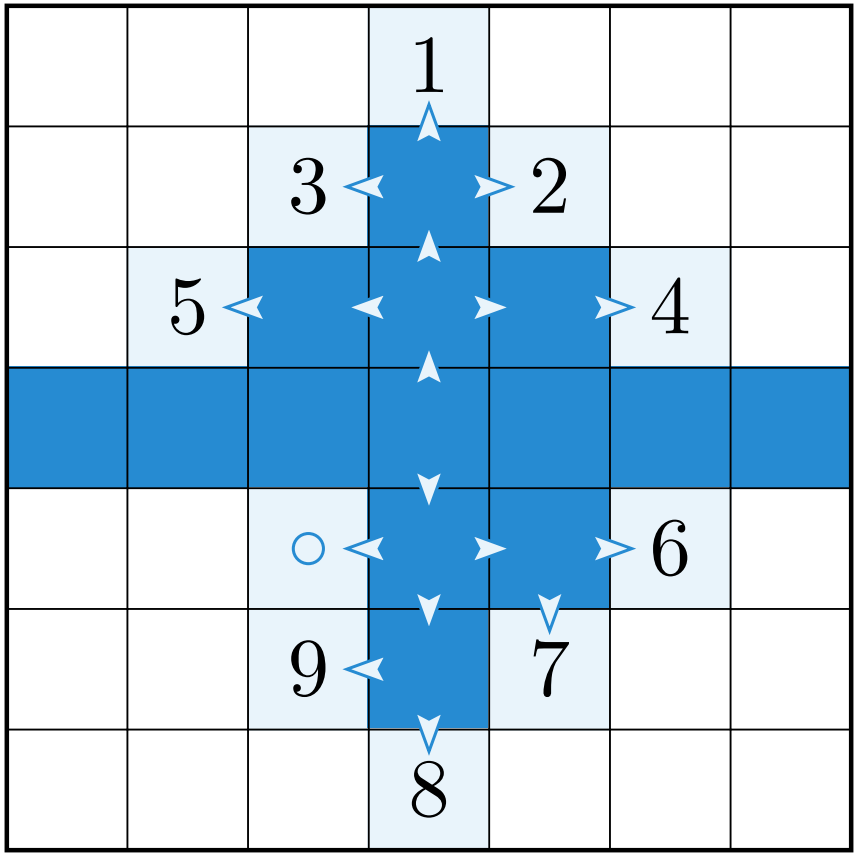
BFS: Naboer stiller seg i kø



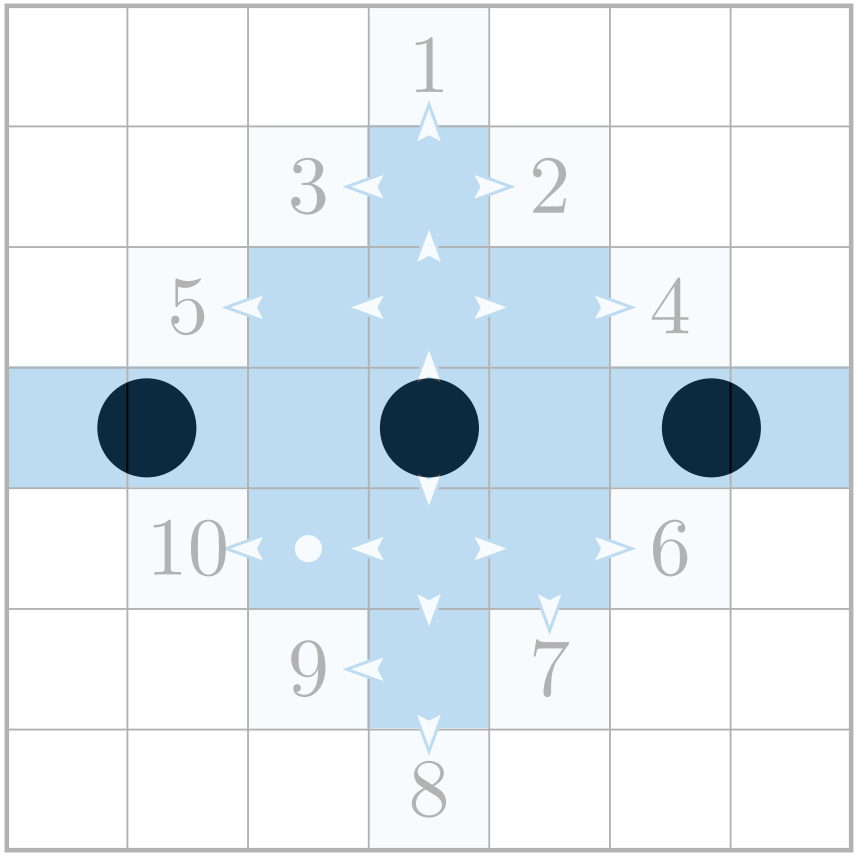
BFS: Naboer stiller seg i kø



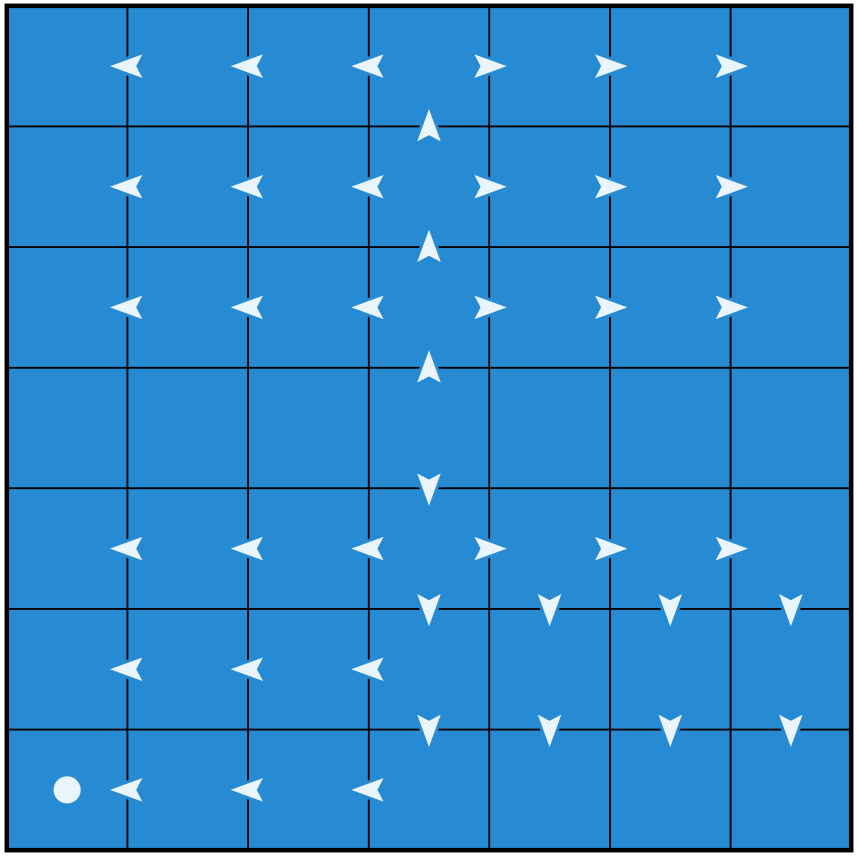
BFS: Naboer stiller seg i kø



BFS: Naboer stiller seg i kø



BFS: Naboer stiller seg i kø



BFS: Naboer stiller seg i kø

Iterativ DFS

ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

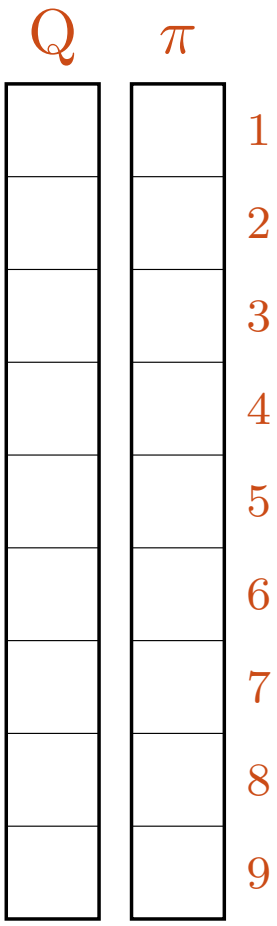
ITER-DFS-VISIT(G, s)

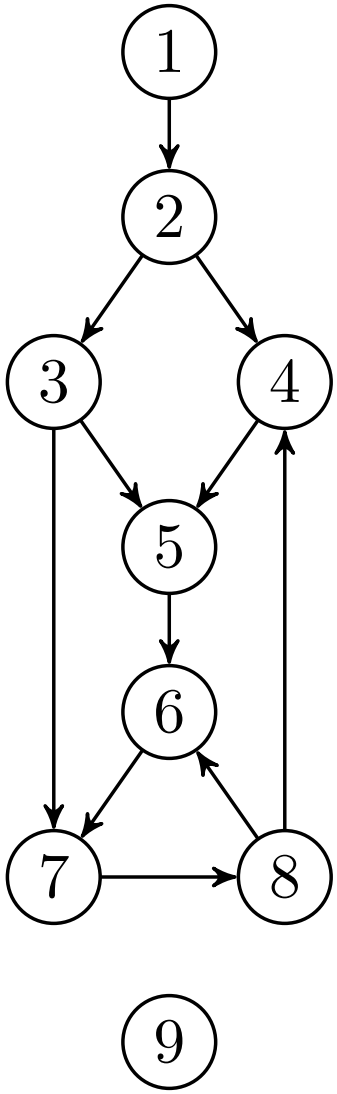
```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = -, -$

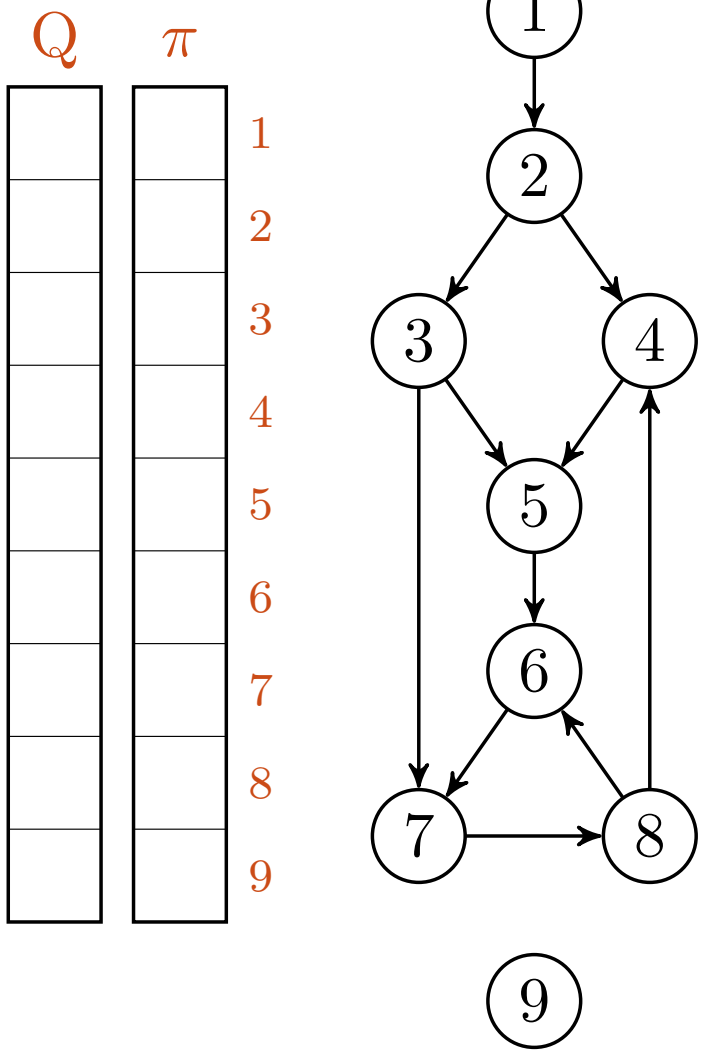




ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

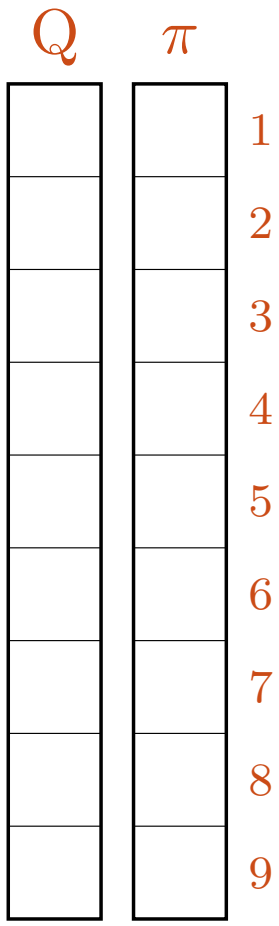
$u, v = 2, -$

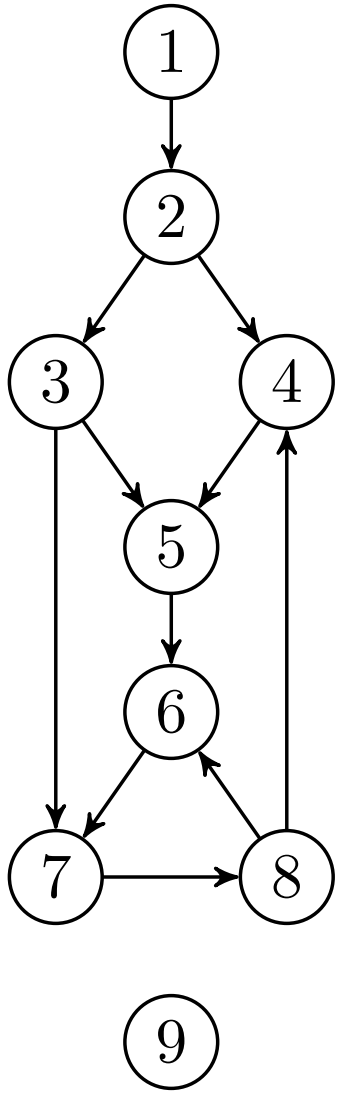


ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = 2, -$





ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
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5  Q = ∅
6  PUSH(Q, s)
7  ...
```
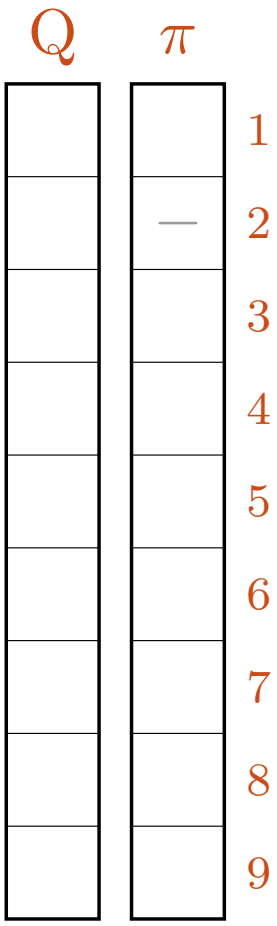
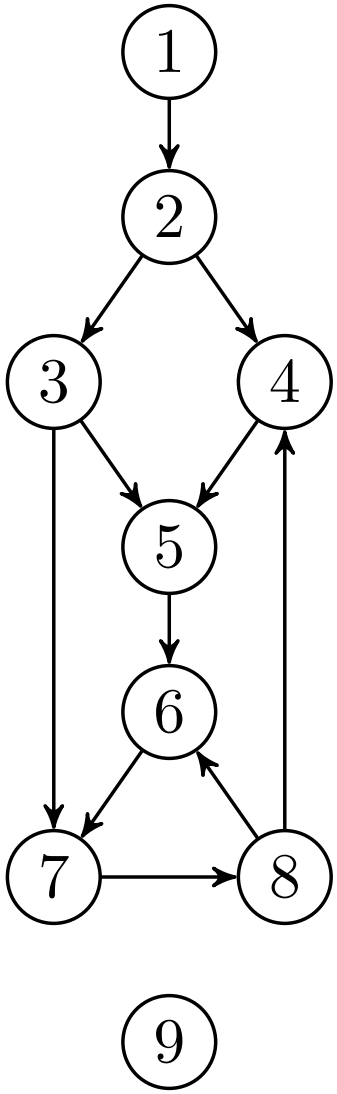

$u, v = 2, -$

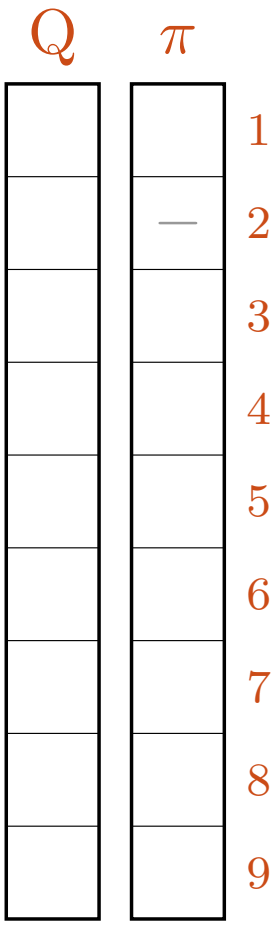


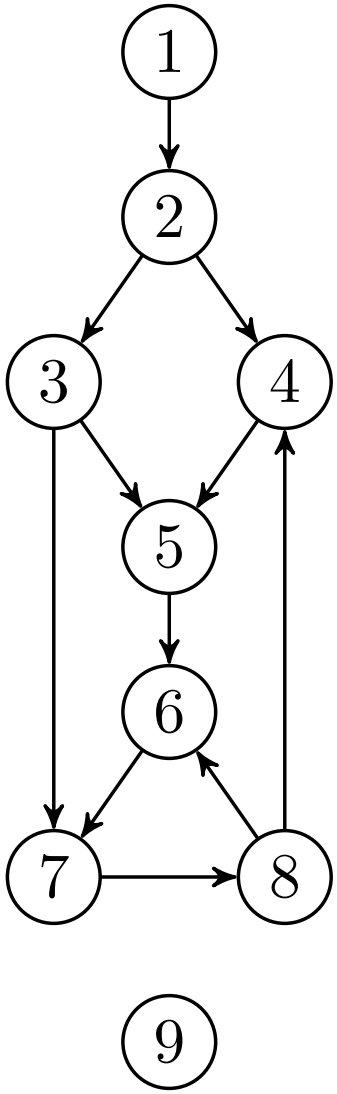


ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = 3, -$

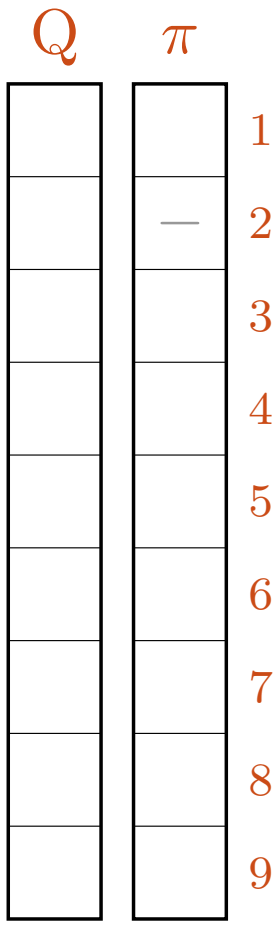


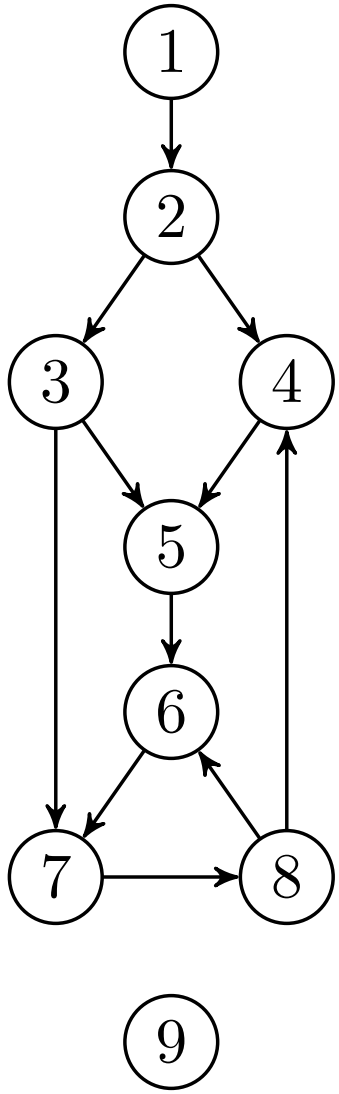


ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = 3, -$

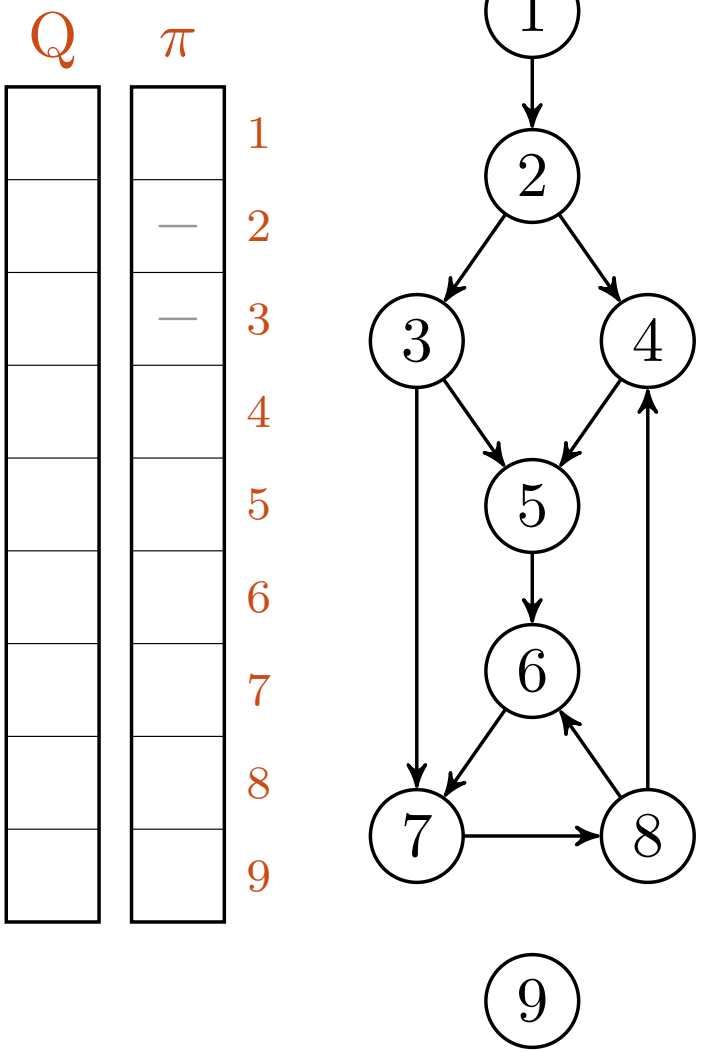




ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

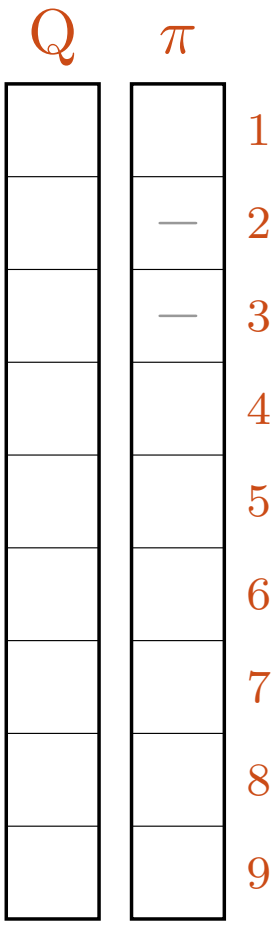
$u, v = 3, -$

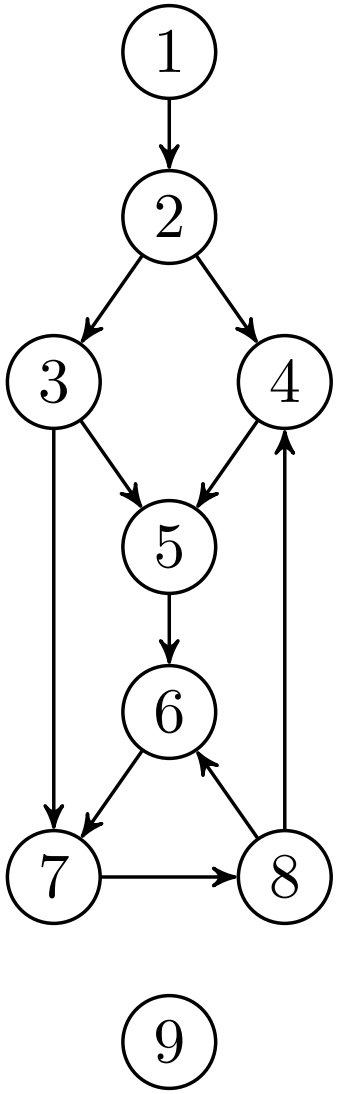


ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = 4, -$

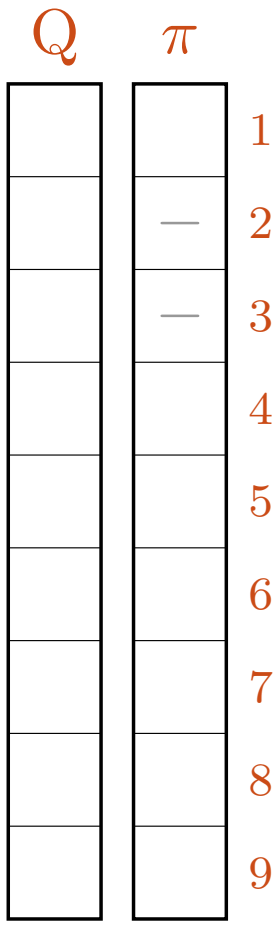


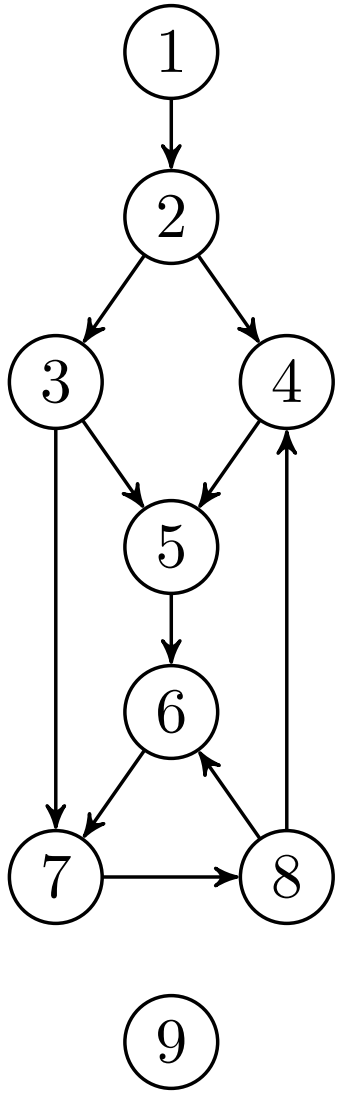


ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = 4, -$





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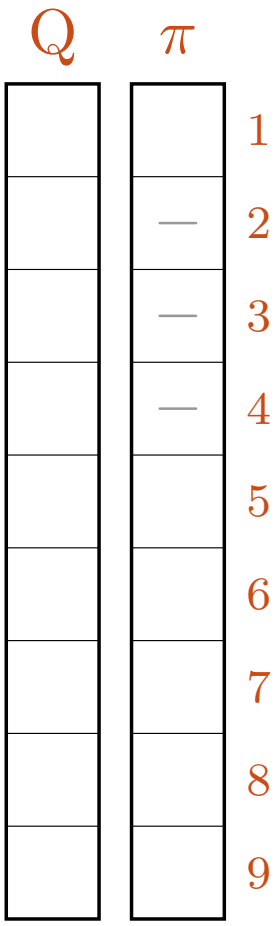
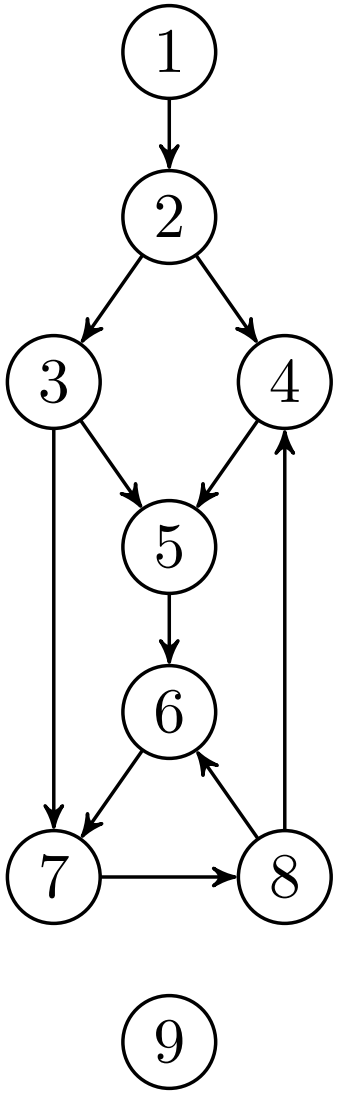
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = 4, -$





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2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```
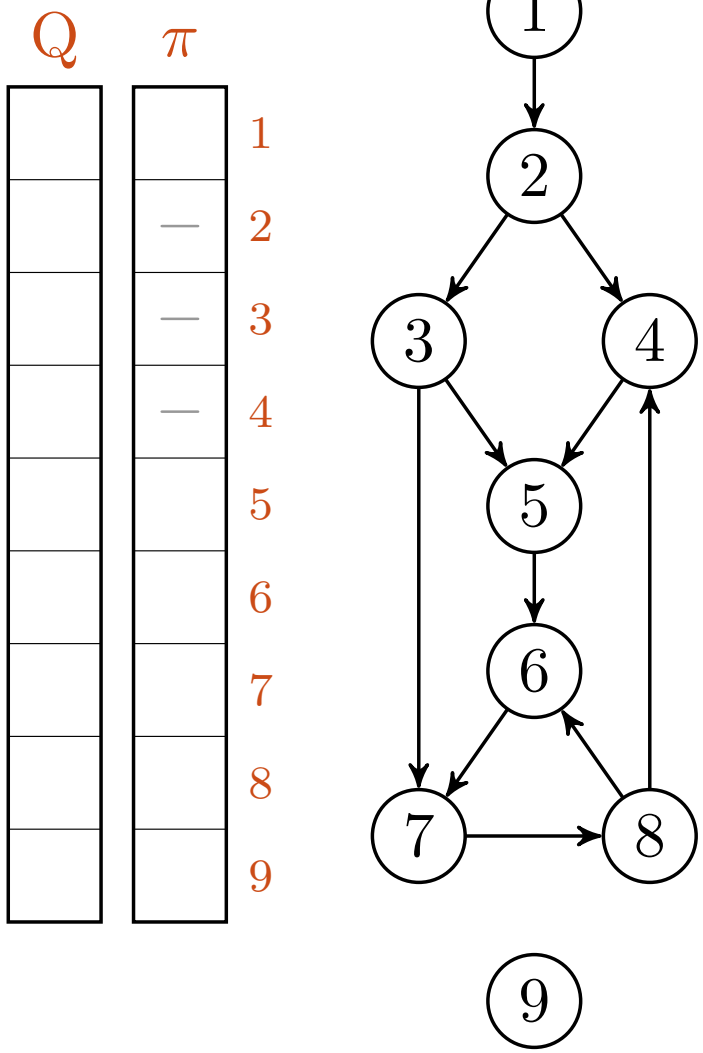
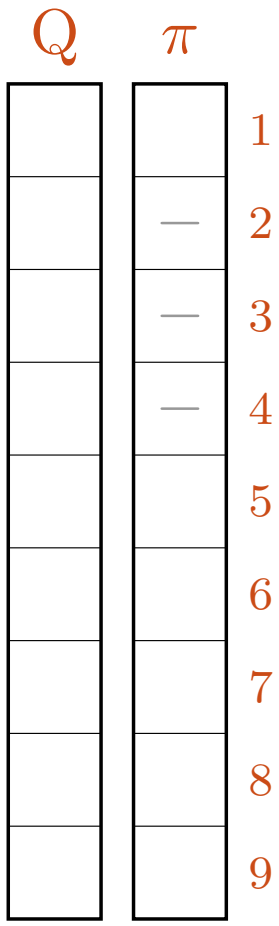

$u, v = 5, -$

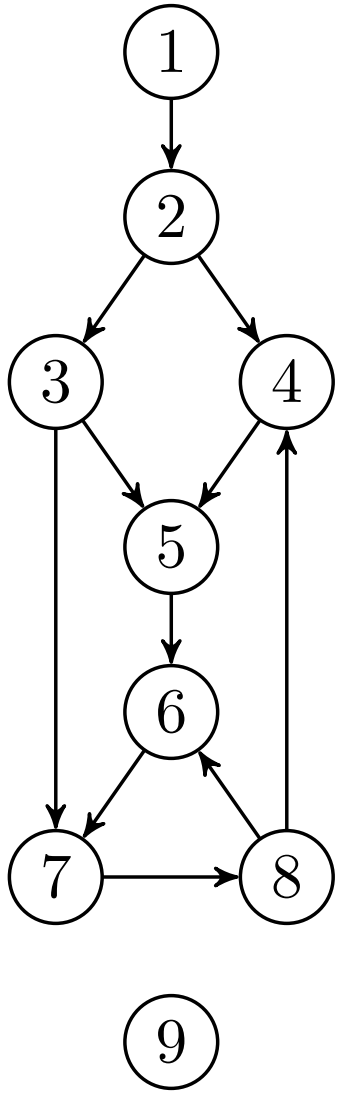


ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = 5, -$





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```
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7  ...
```
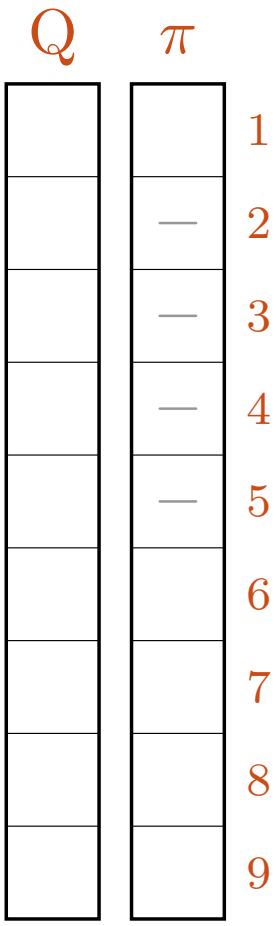
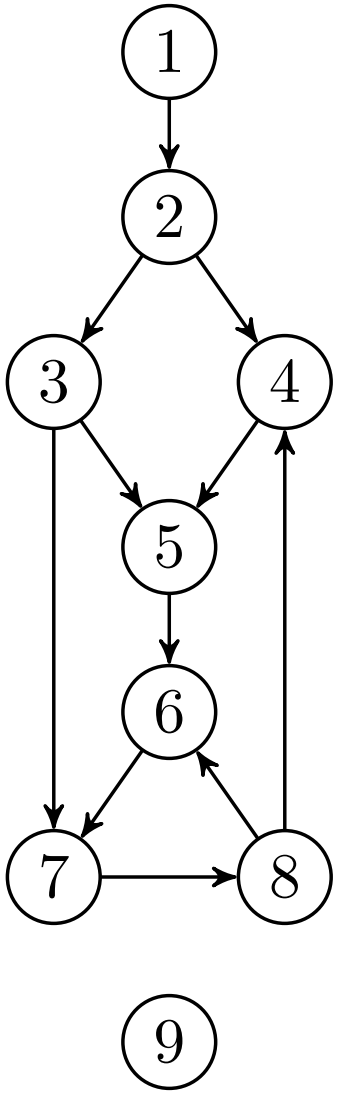

$u, v = 5, -$





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```
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2        u.color = WHITE
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4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```
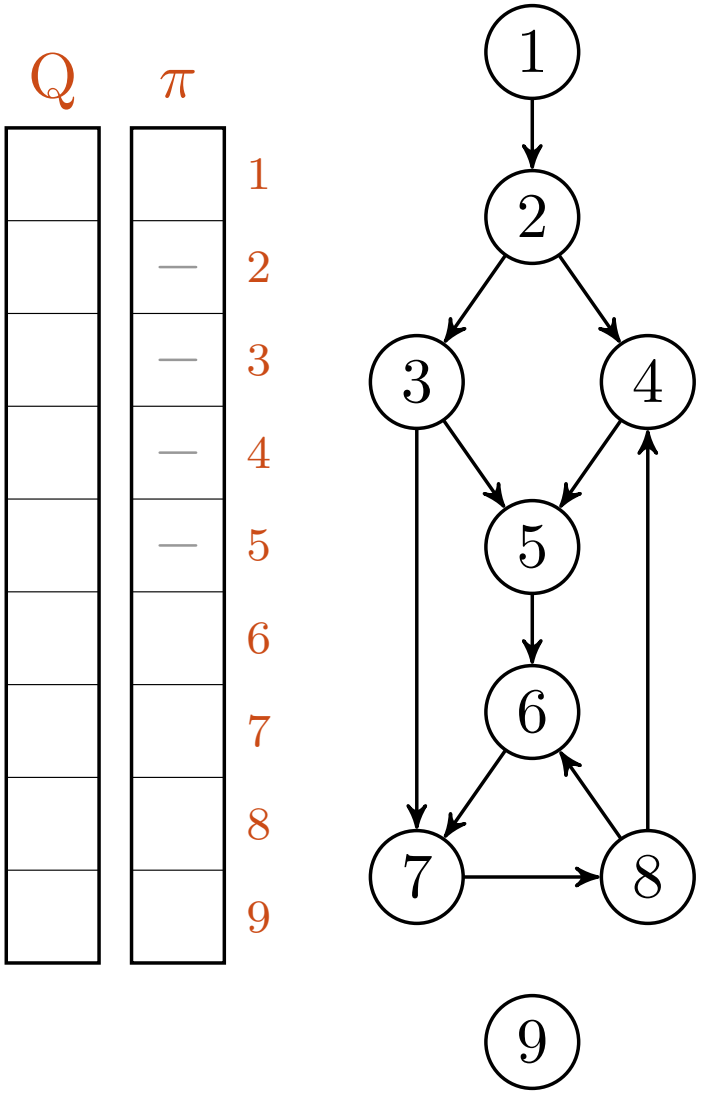

$u, v = 6, -$



ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
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6  PUSH(Q, s)
7  ...
```
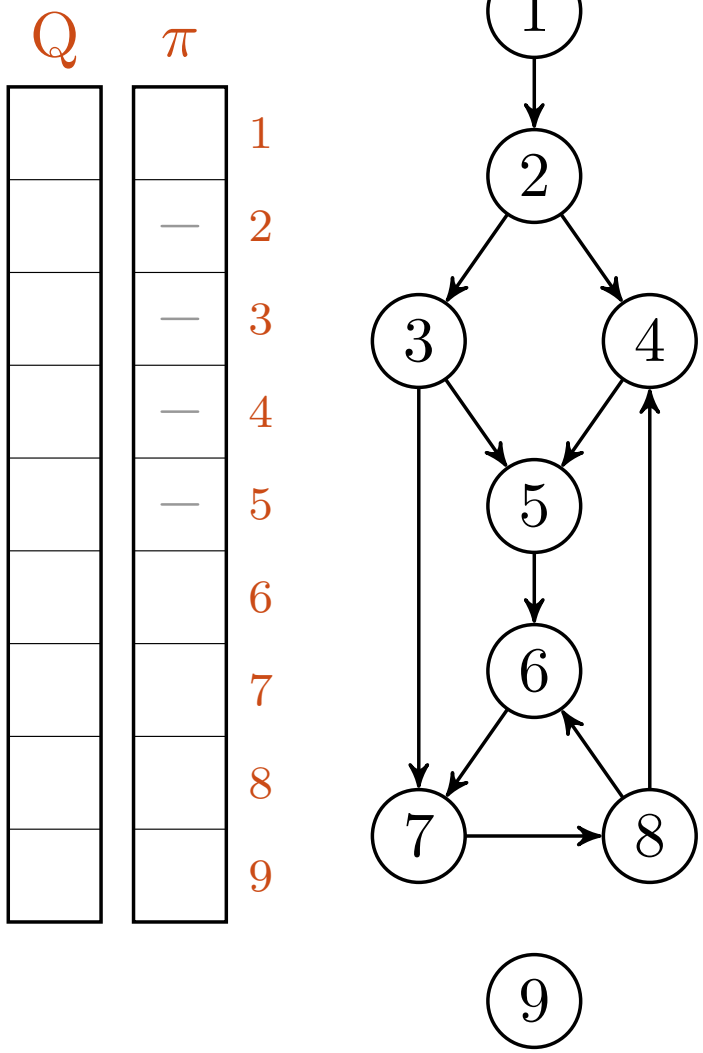

$u, v = 6, -$



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```
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7  ...
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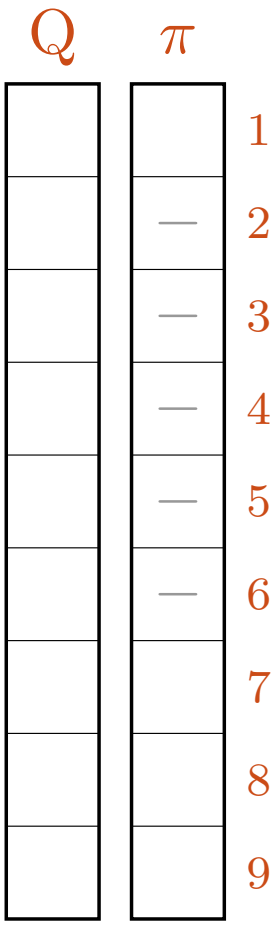
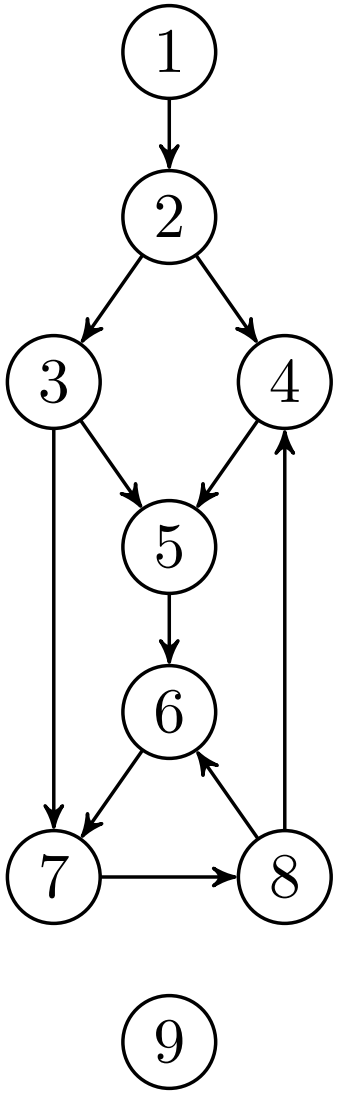
$u, v = 6, -$





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4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```
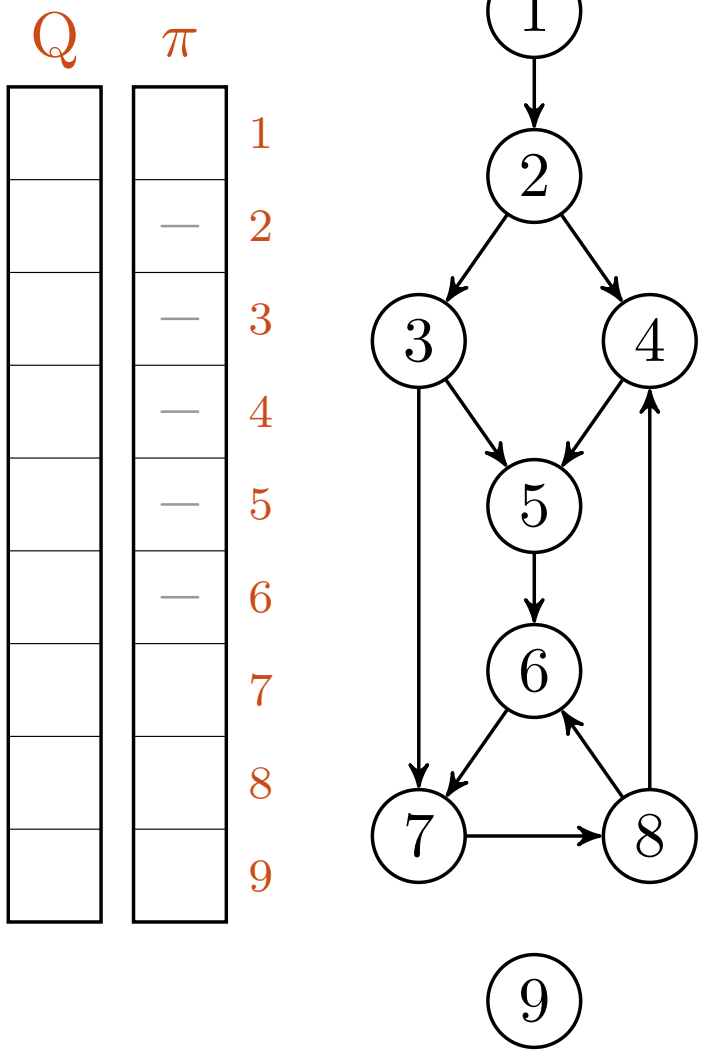

$u, v = 7, -$



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```
1  for each vertex u ∈ G.V − {s}
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3        u.π = NIL
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5  Q = ∅
6  PUSH(Q, s)
7  ...
```
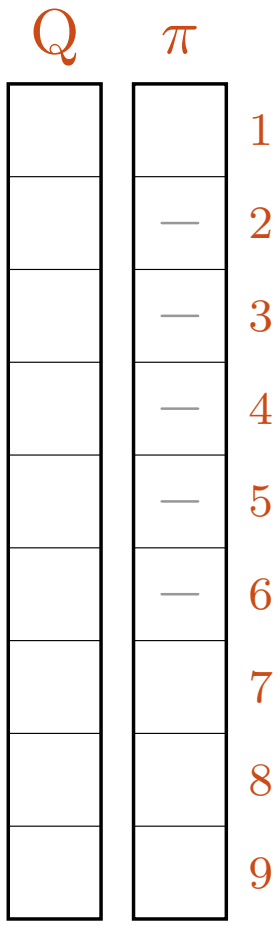
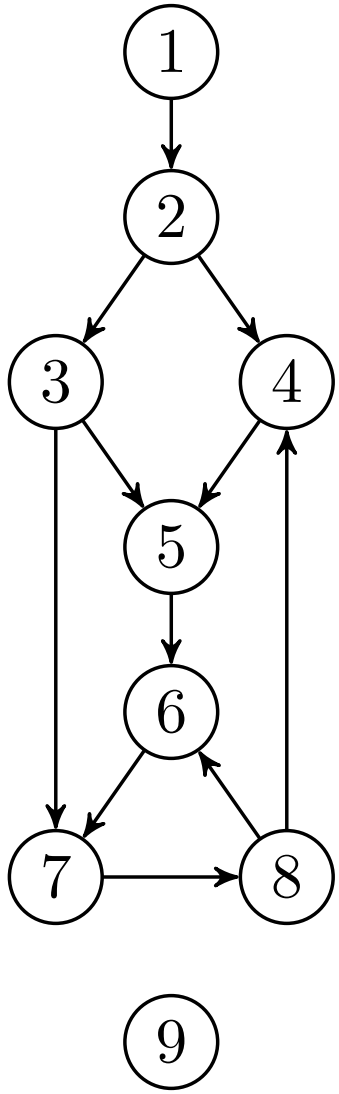

$u, v = 7, -$





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6  PUSH(Q, s)
7  ...
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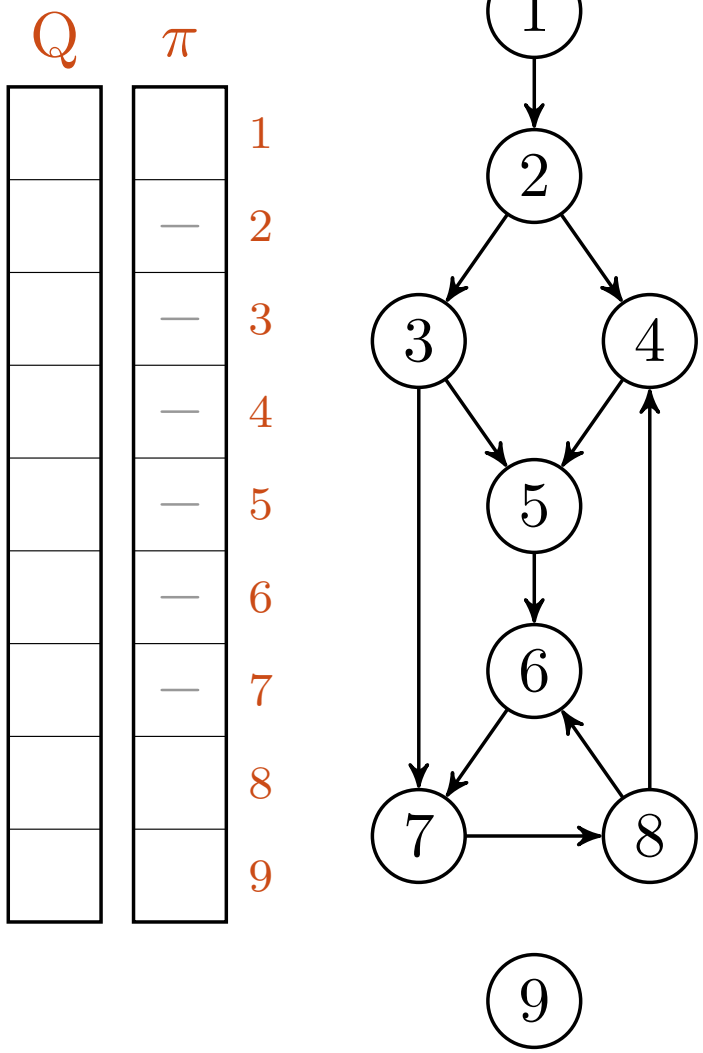
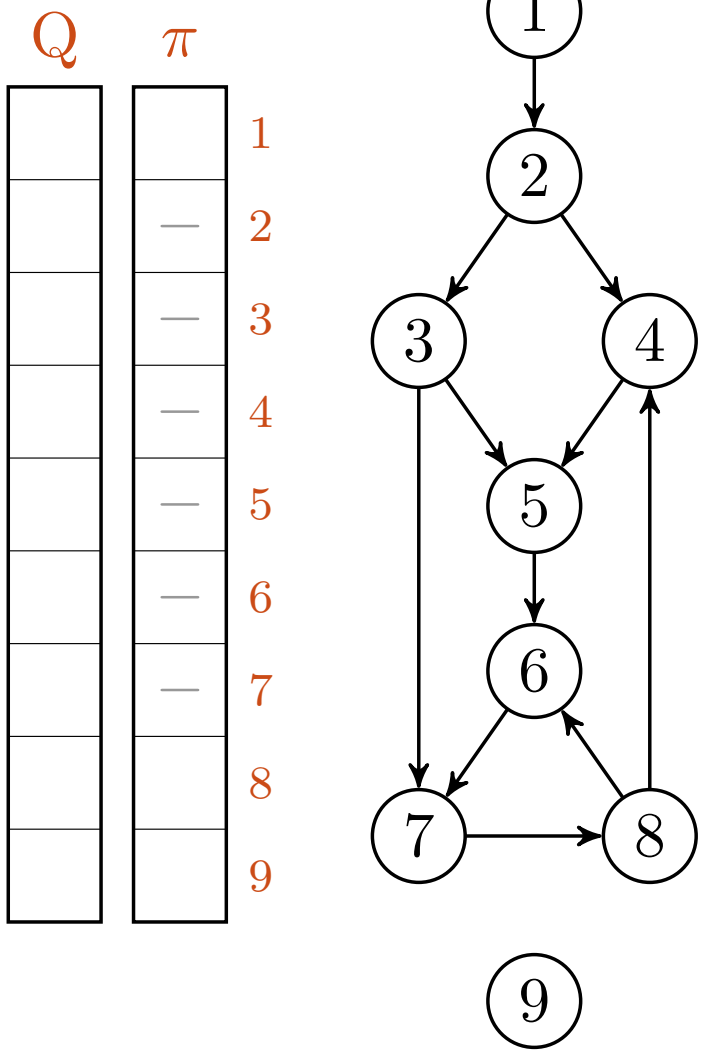
$u, v = 7, -$



ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = 8, -$



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```
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5  Q = ∅
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7  ...
```
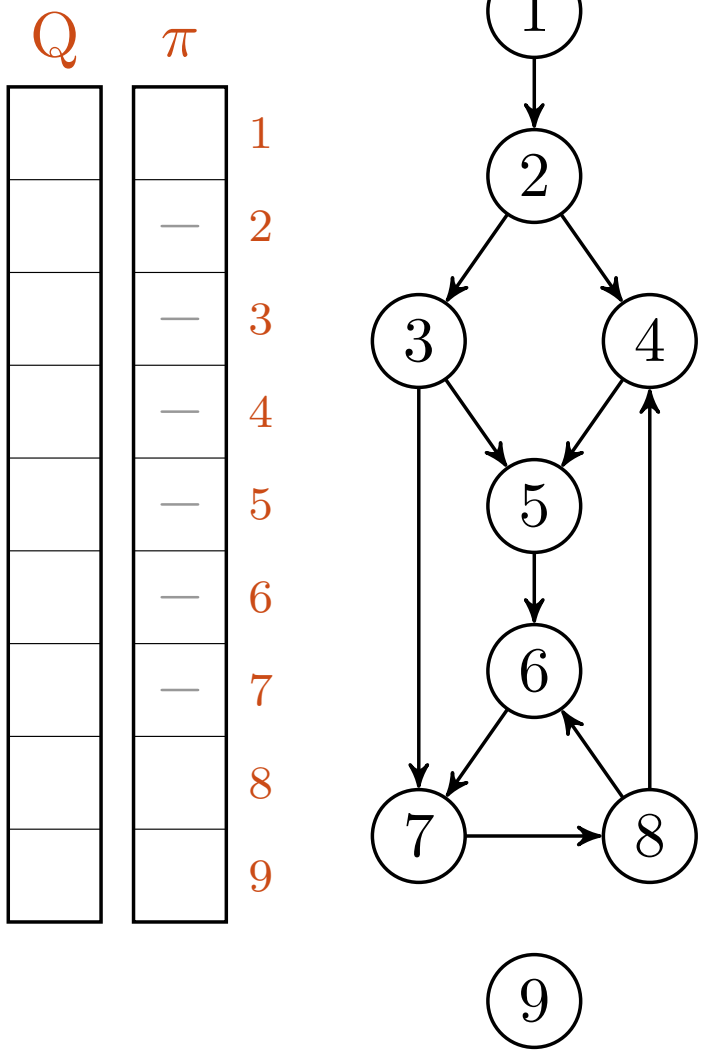

$u, v = 8, -$



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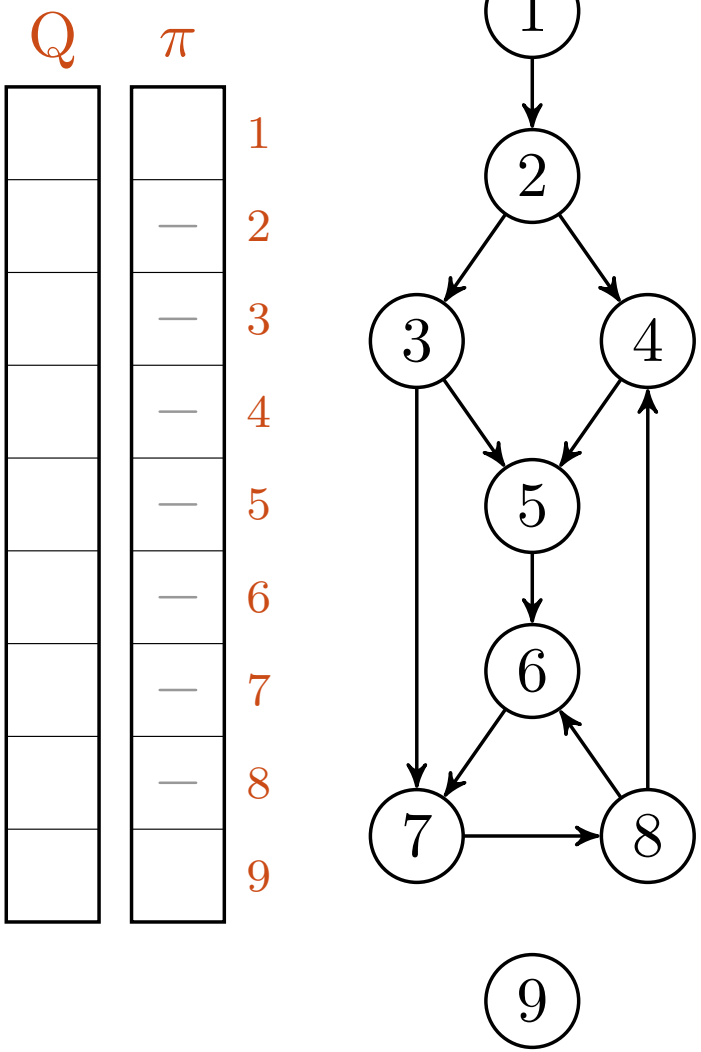
```

$u, v = 8, -$



ITER-DFS-VISIT(G, s)

```
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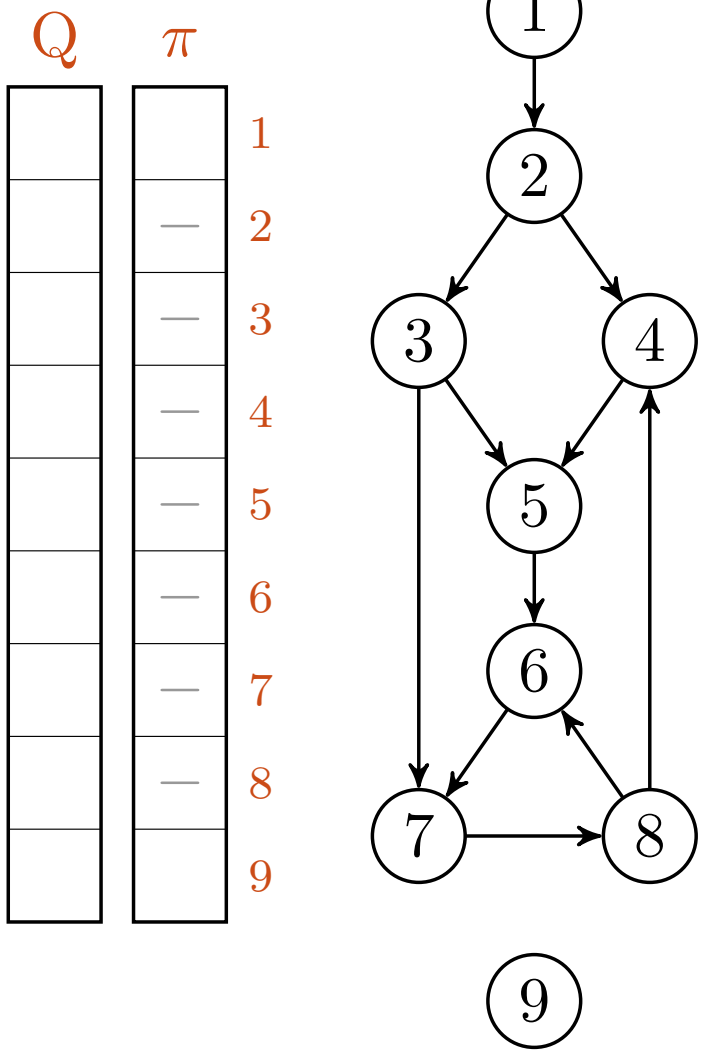
2        u.color = WHITE
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = 9, -$



ITER-DFS-VISIT(G, s)

```
1  for each vertex u ∈ G.V − {s}
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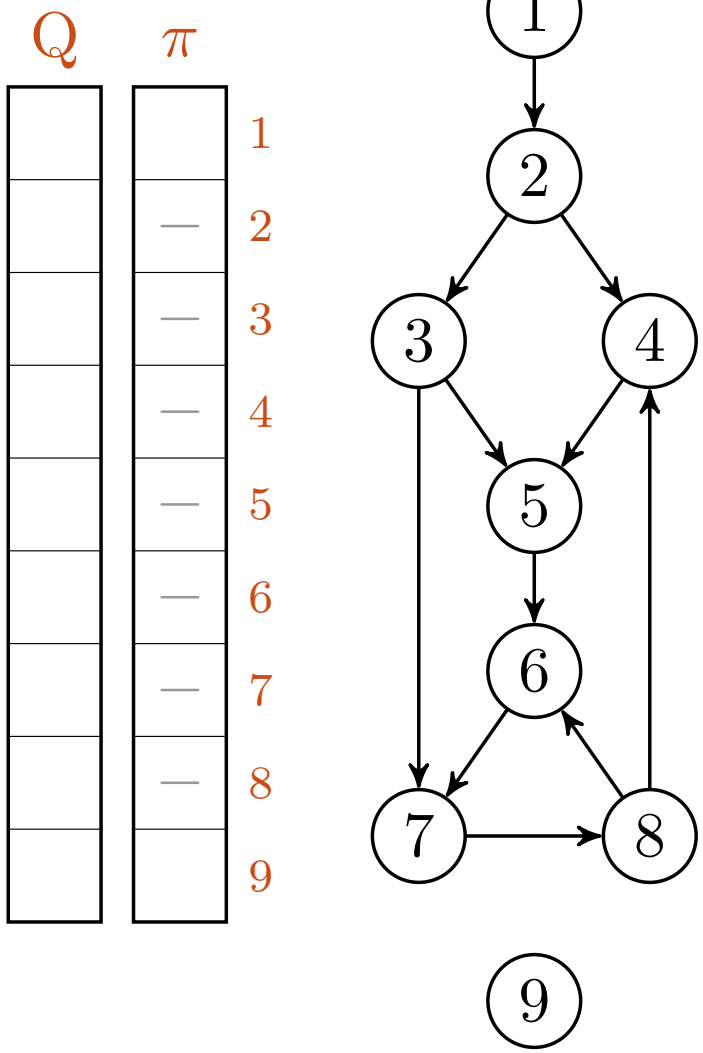
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = 9, -$



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```
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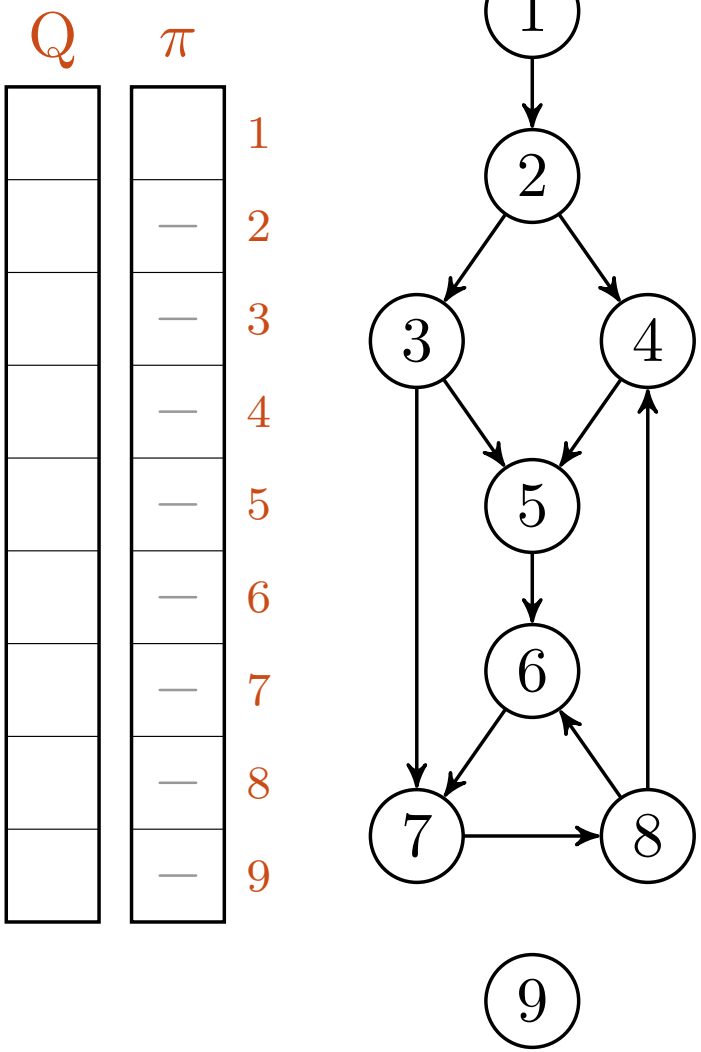
3        u.π = NIL
4  s.π = NIL
5  Q = ∅
6  PUSH(Q, s)
7  ...
```

$u, v = -, -$



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```
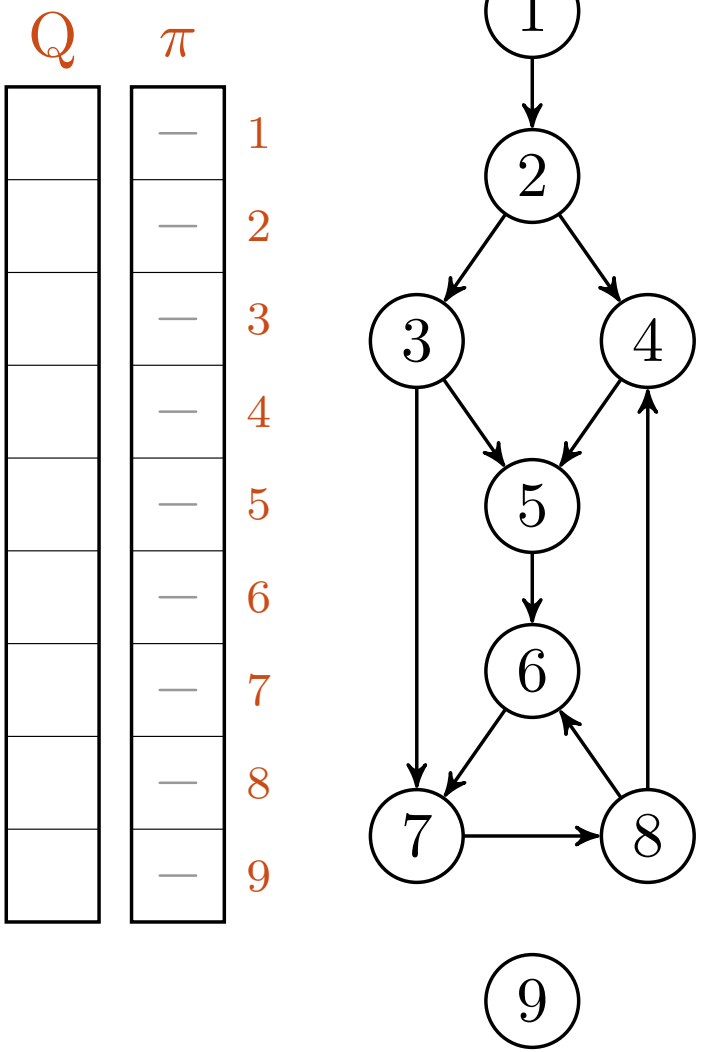

$u, v = -, -$



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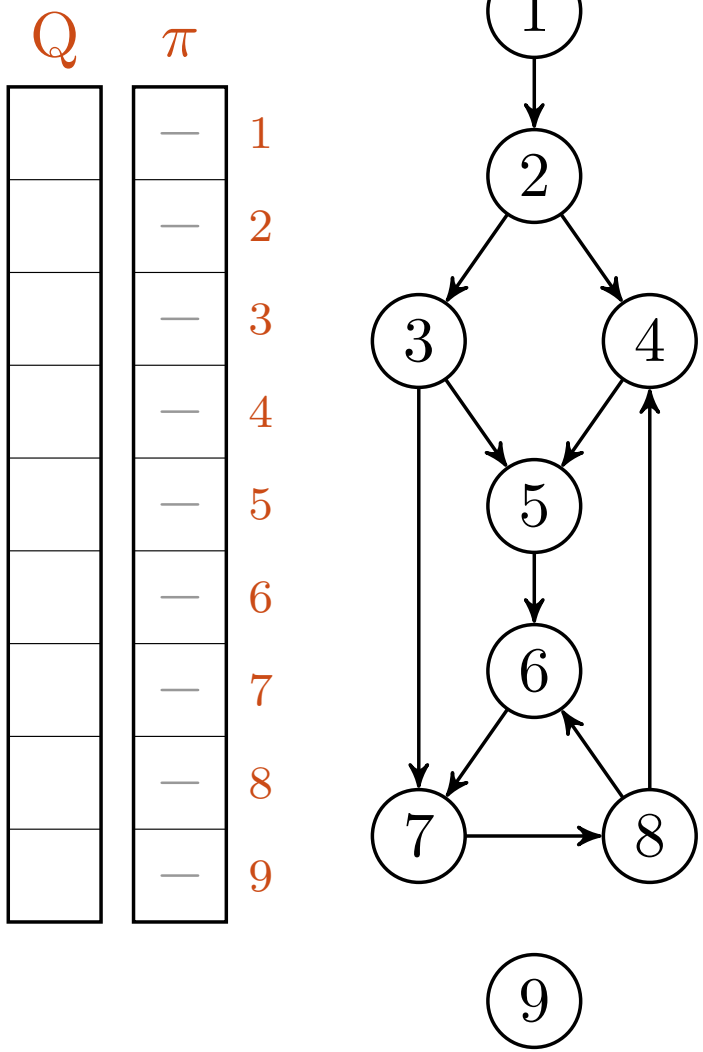

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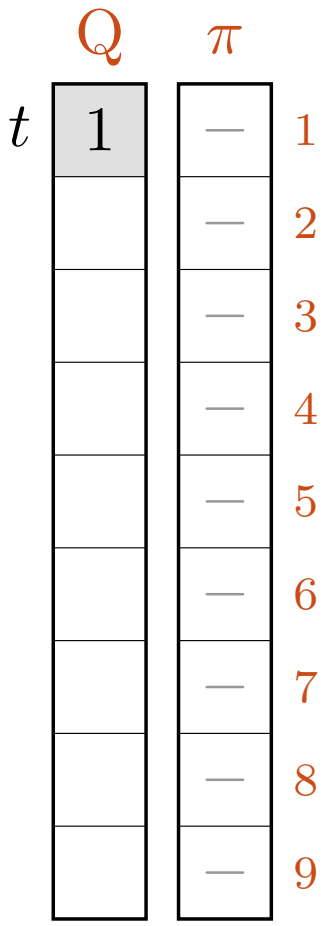
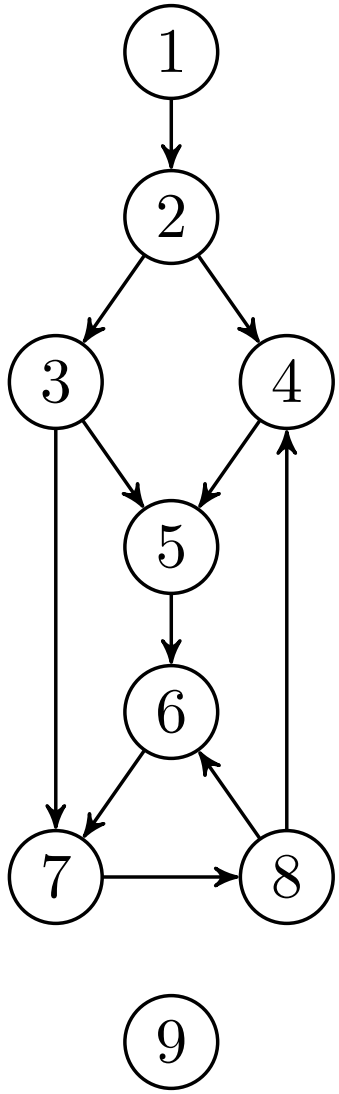
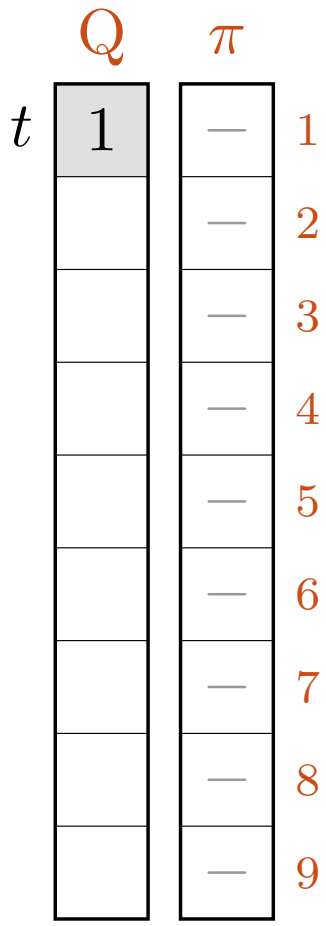
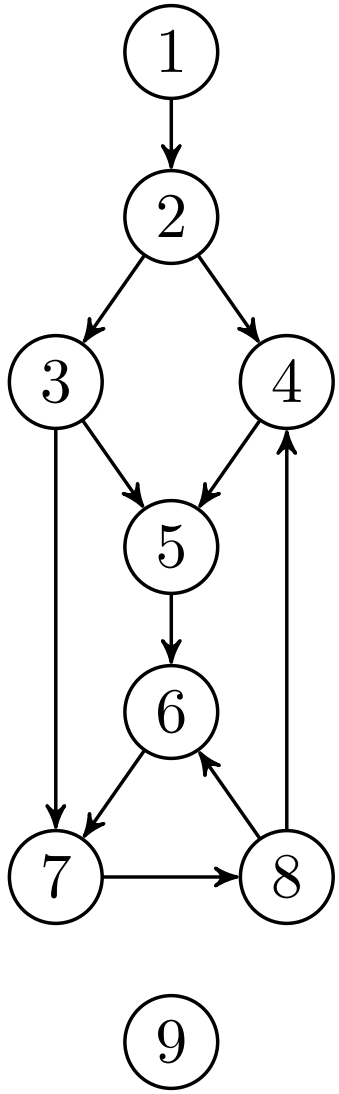




```
ITER-DFS-VISIT(G, s)
 6  ...
 7  while Q ≠ ∅
 8      u = PEEK(Q)
 9      if u.color ≠ WHITE
10          u.color = BLACK
11          POP(Q)
12          continue
13      u.color = GRAY
14      for each v ∈ G.Adj[u]
15          if v.color == WHITE
16              v.π = u
17              PUSH(Q, v)
```

$u, v = -, -$





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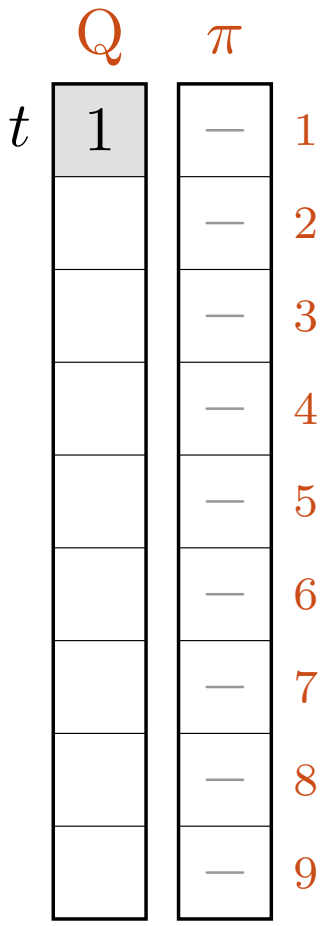
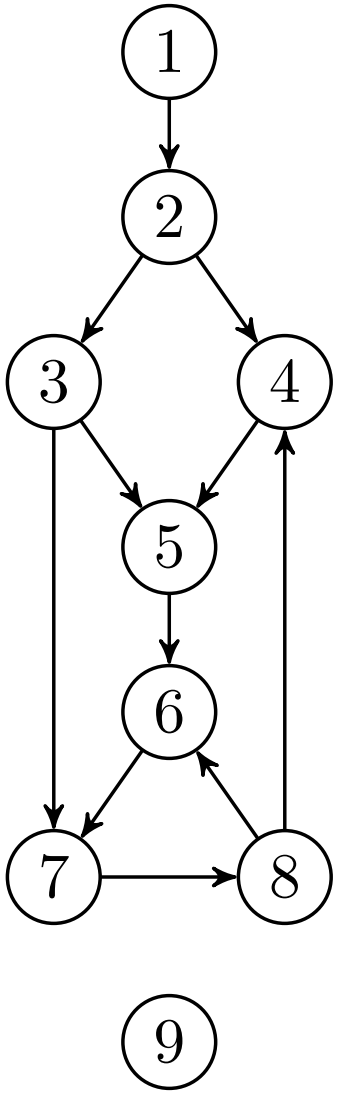
```

u, v = –, –





```
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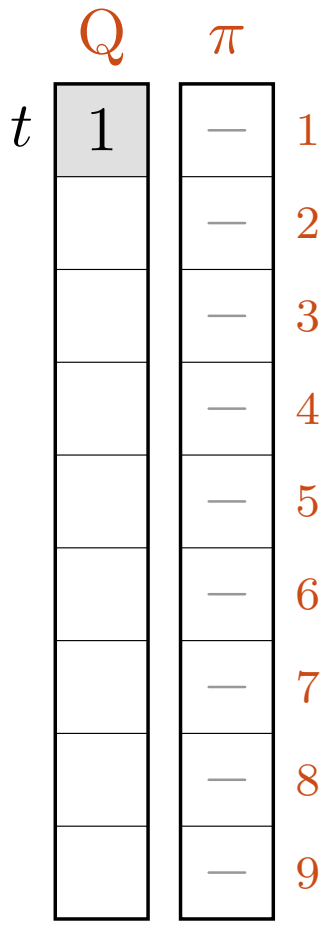
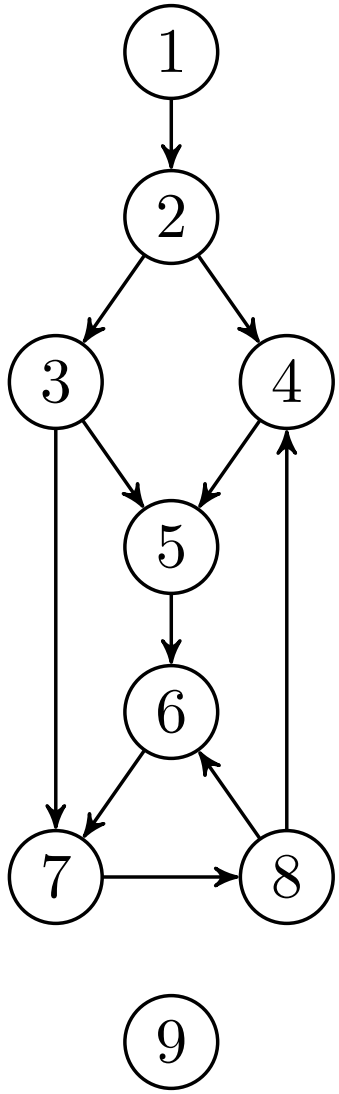
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v = 1, -$





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 9        if u.color ≠ WHITE
10              u.color = BLACK
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12              continue
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14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```
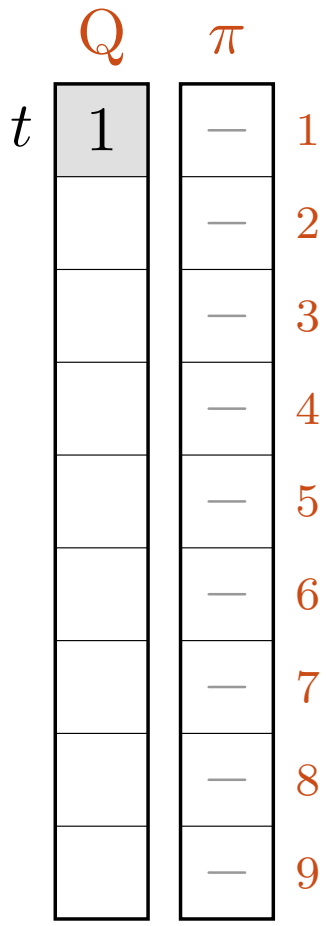
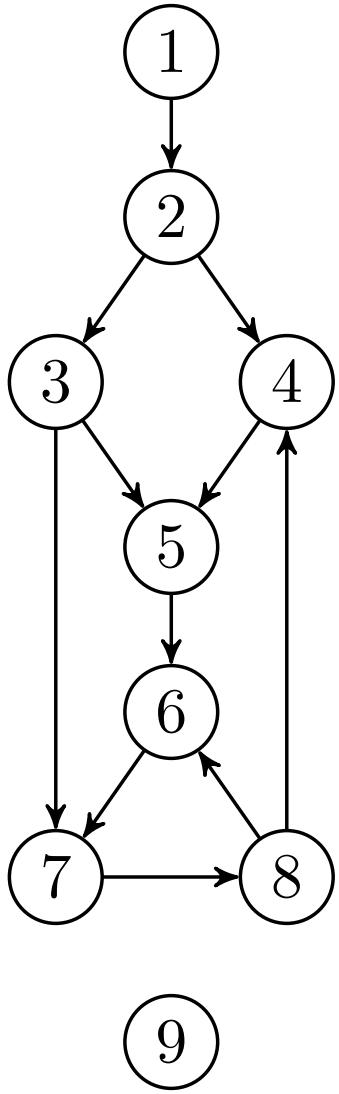

$u, v = 1, -$





ITER-DFS-VISIT(G, s)

```
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 9        if u.color ≠ WHITE
10              u.color = BLACK
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15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
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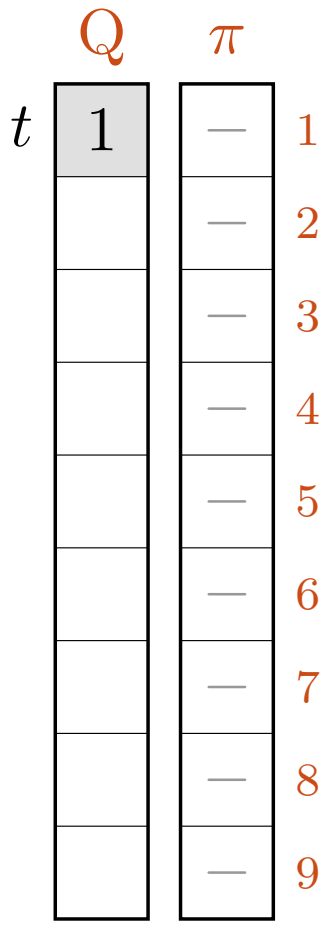
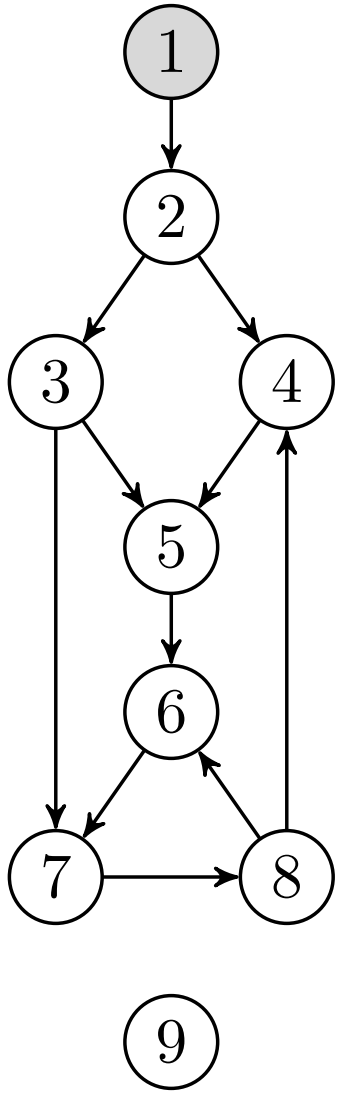
$u, v = 1, -$

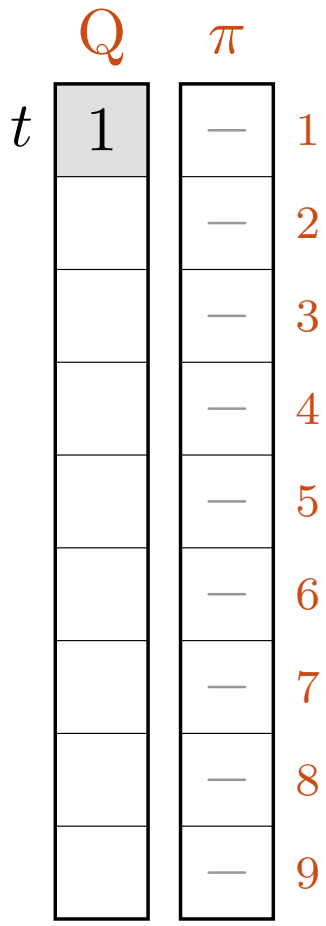


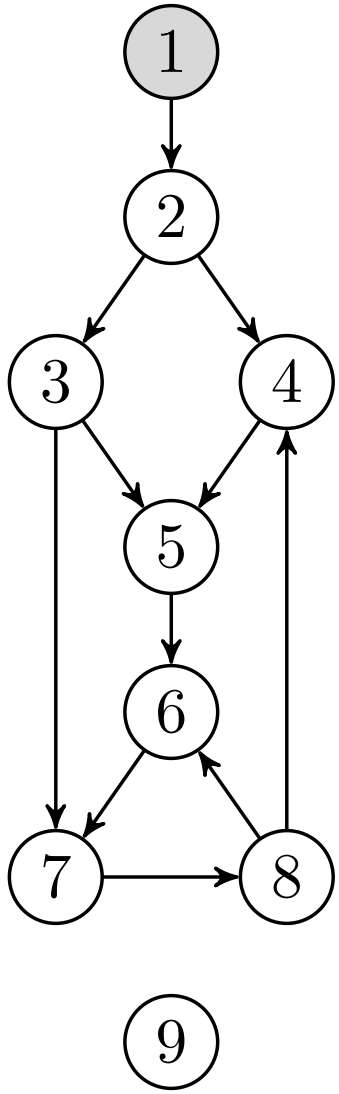


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v = 1, 2$





ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
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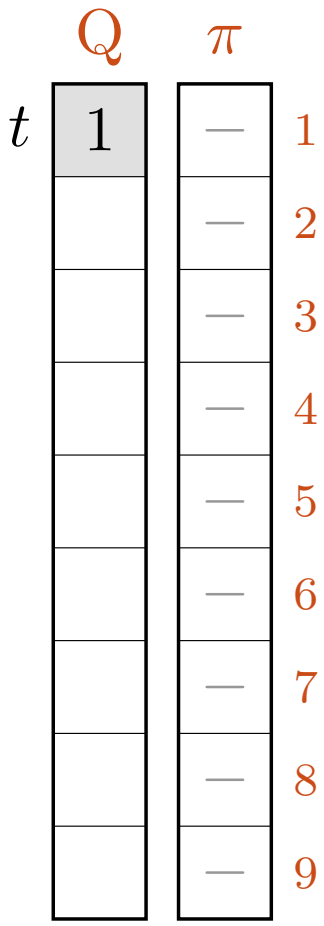
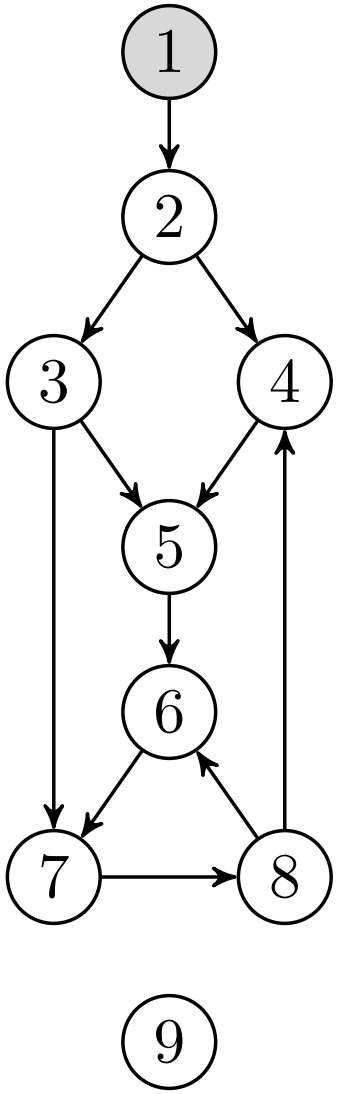
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v = 1, 2$

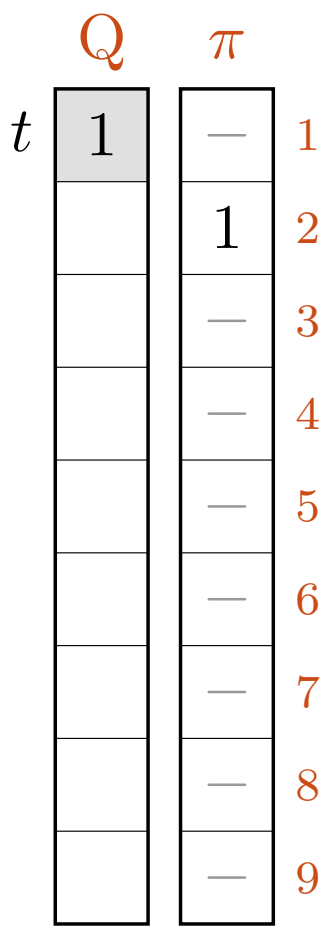


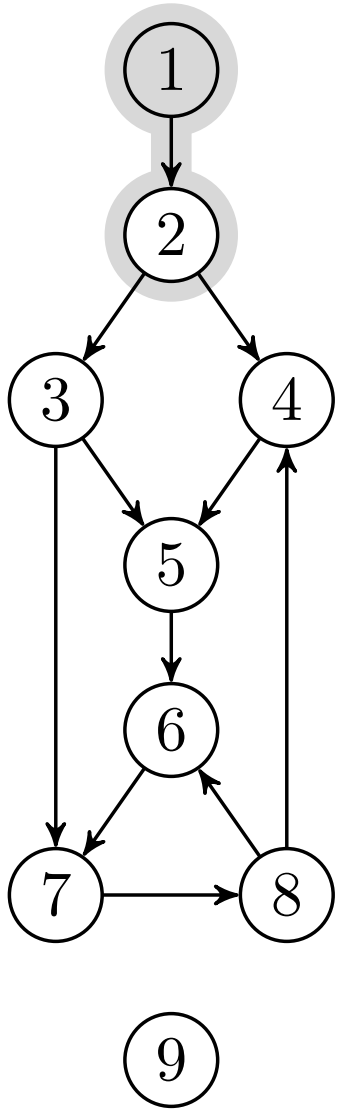


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v = 1, 2$





ITER-DFS-VISIT(G, s)

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 6  ...
 7  while Q ≠ ∅
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15          if v.color == WHITE
16              v.π = u
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```
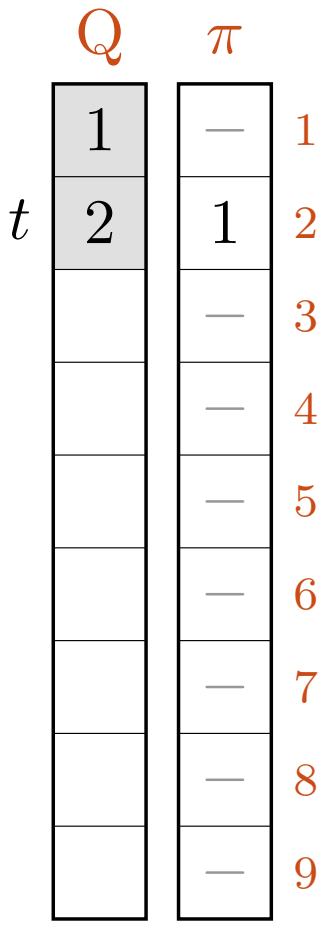
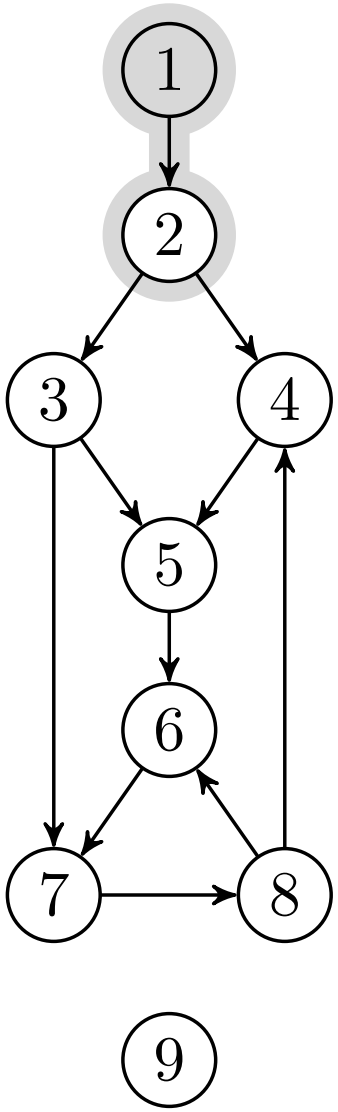

$u, v = 1, 2$





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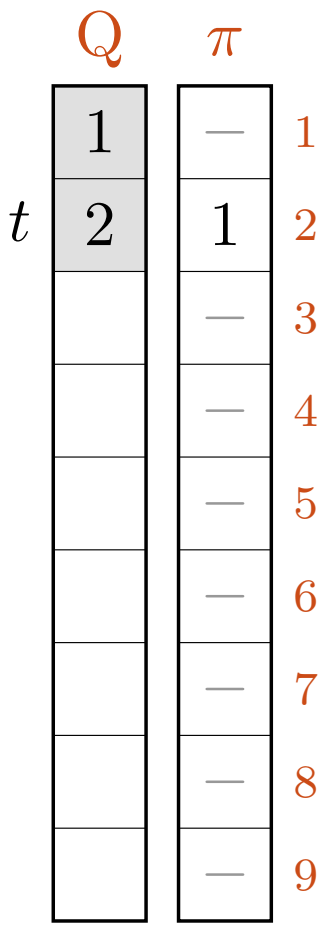
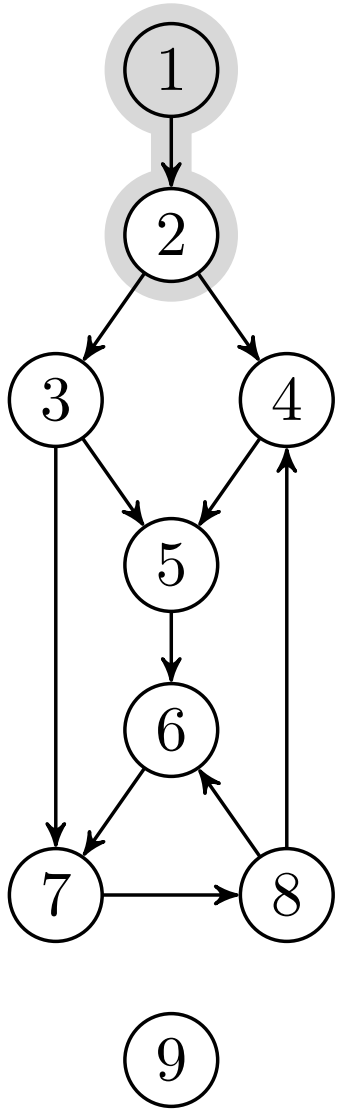
$u, v = 1, 2$





ITER-DFS-VISIT(G, s)

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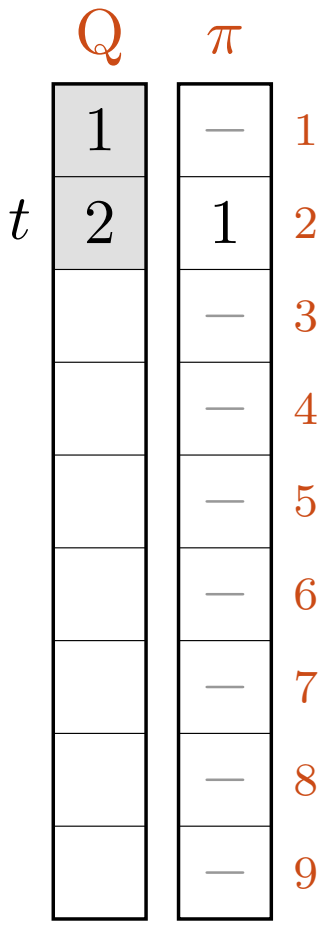
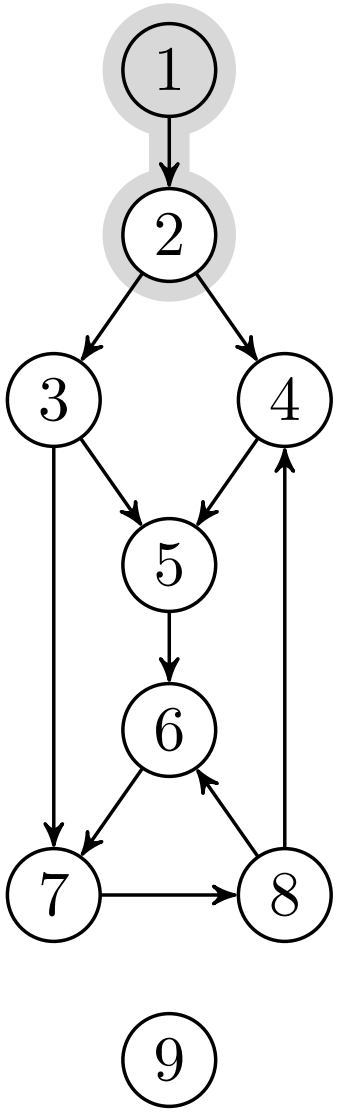
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v \;=\; 2, 2$





ITER-DFS-VISIT(G, s)

```
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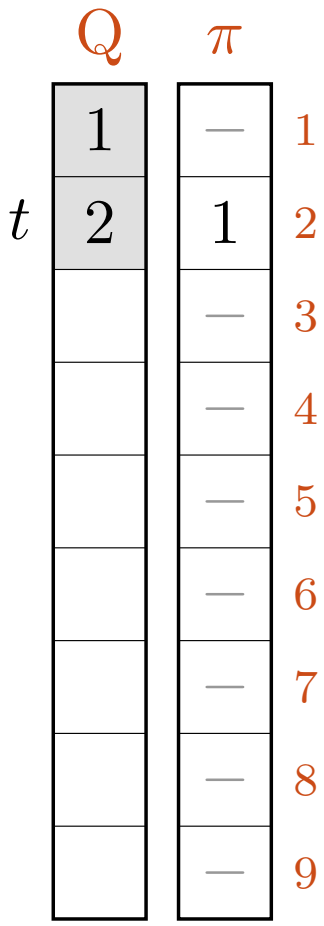
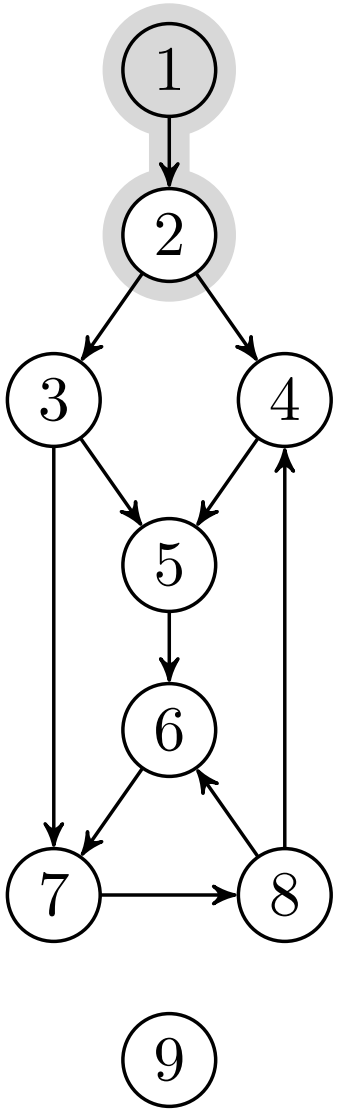
```

$u, v \;=\; 2, 2$





ITER-DFS-VISIT(G, s)

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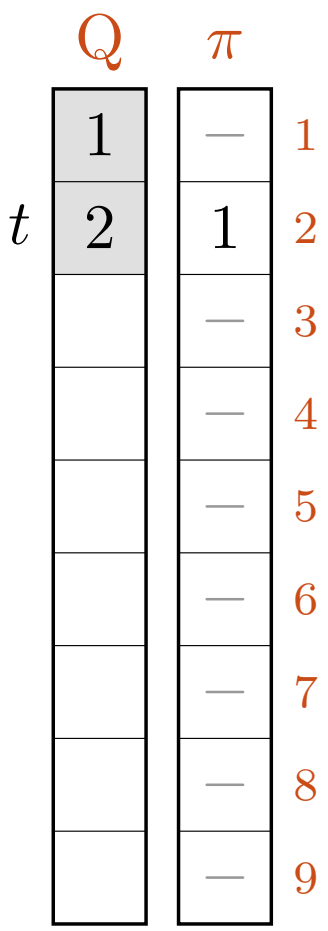
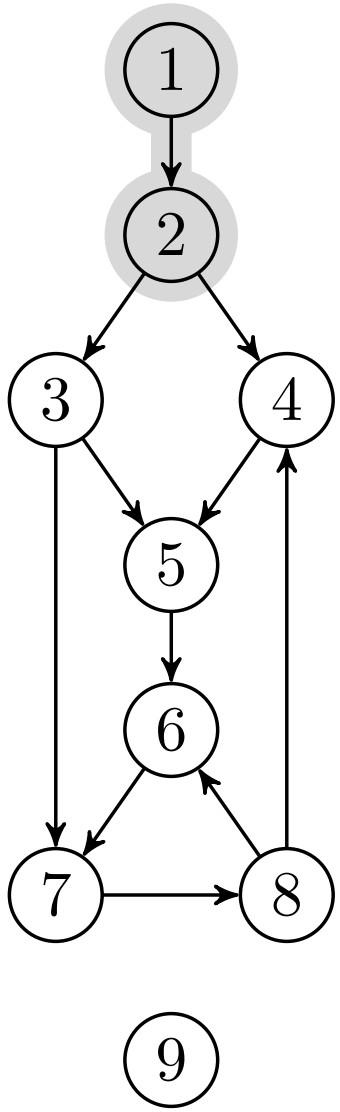
$u, v \;=\; 2, 2$





ITER-DFS-VISIT(G, s)

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16                    v.π = u
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```
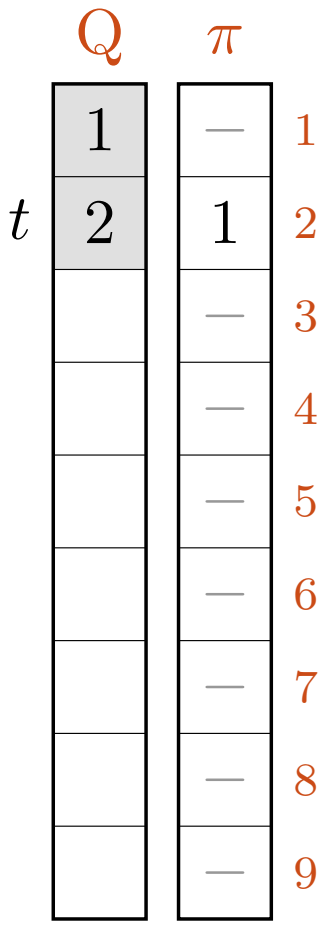
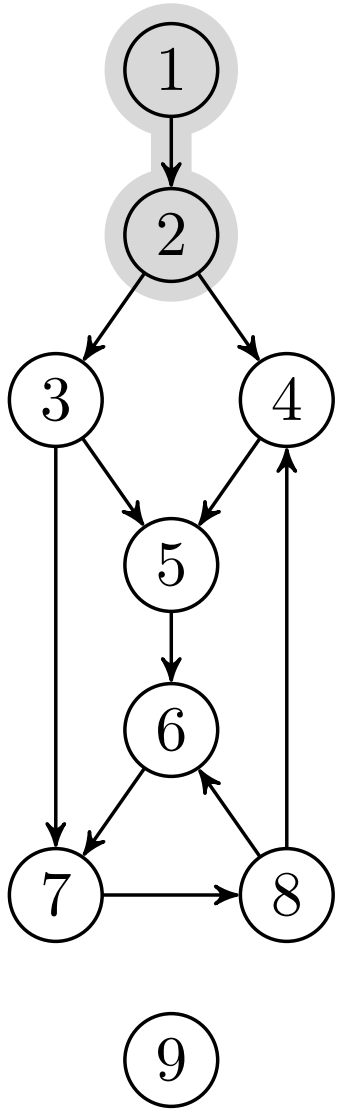

$u, v = 2, 4$





ITER-DFS-VISIT(G, s)

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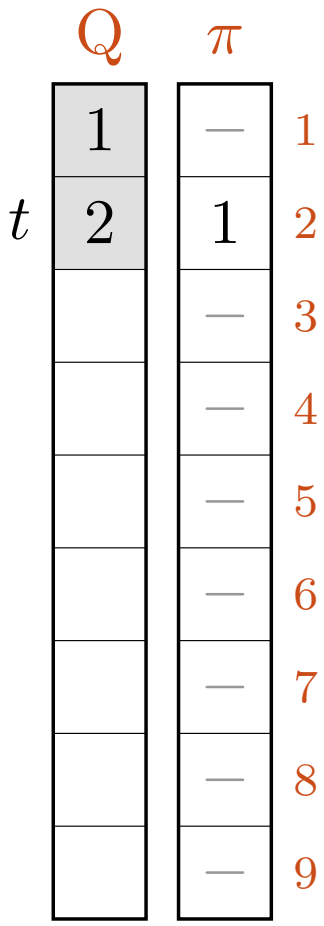
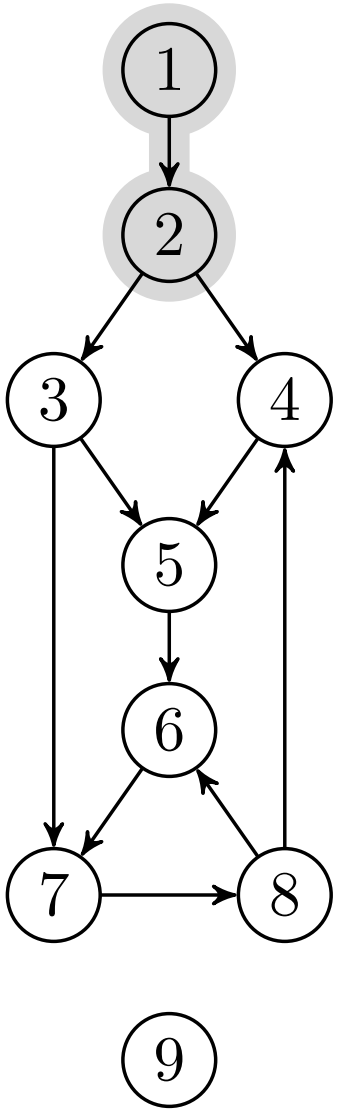
$u, v = 2, 4$





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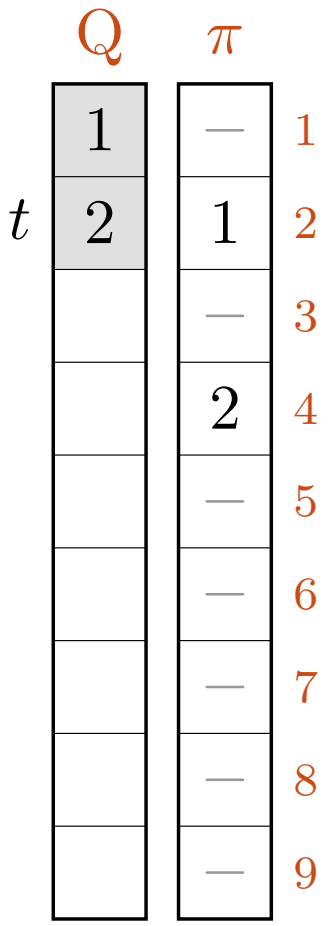

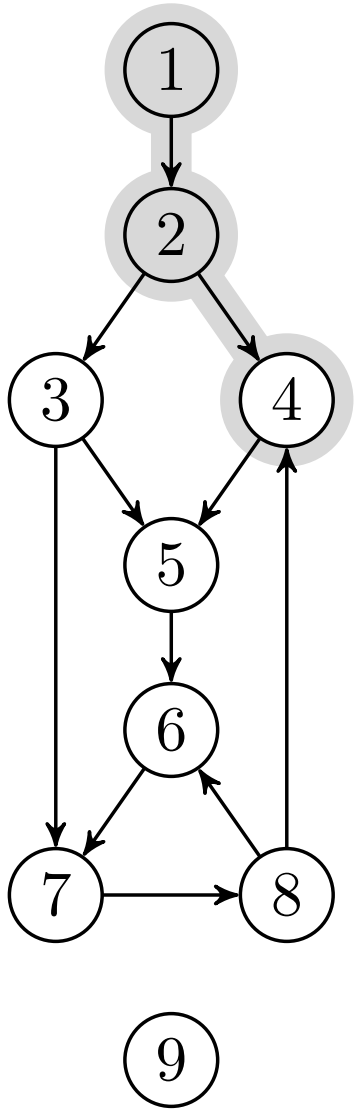

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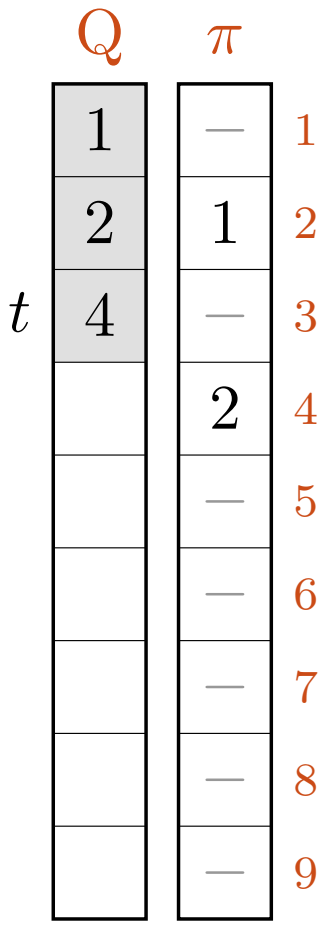
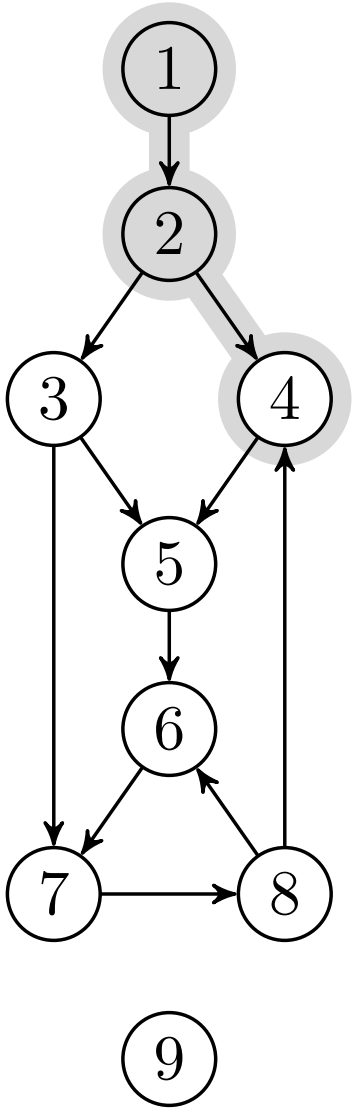
$u, v = 2, 4$





ITER-DFS-VISIT(G, s)

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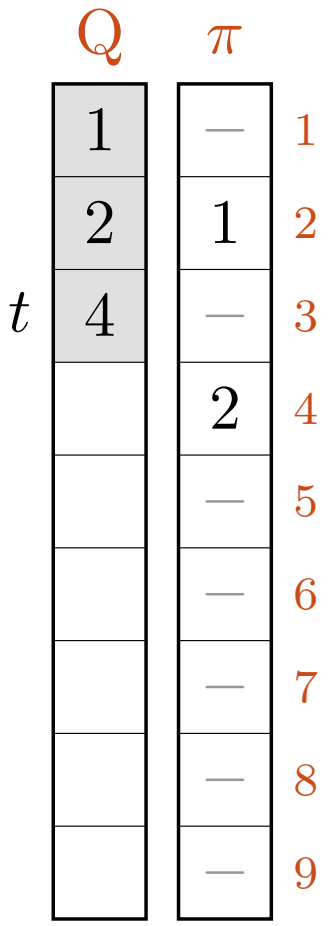
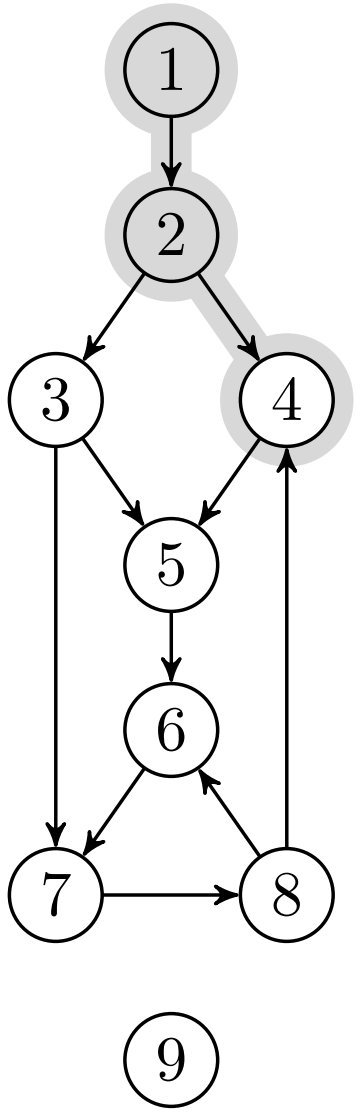
```

$u, v = 2, 3$





ITER-DFS-VISIT(G, s)

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```
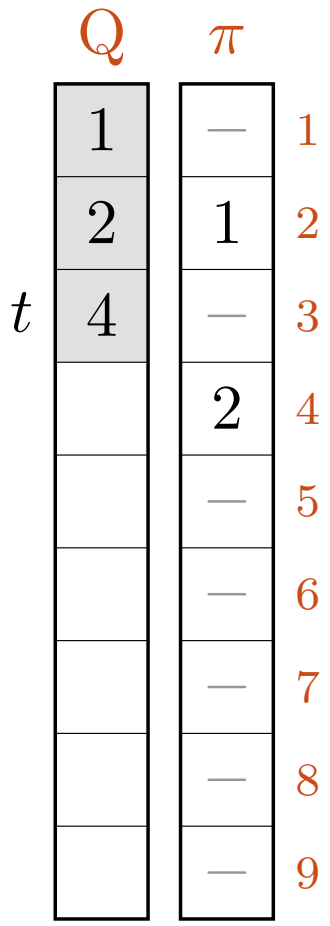
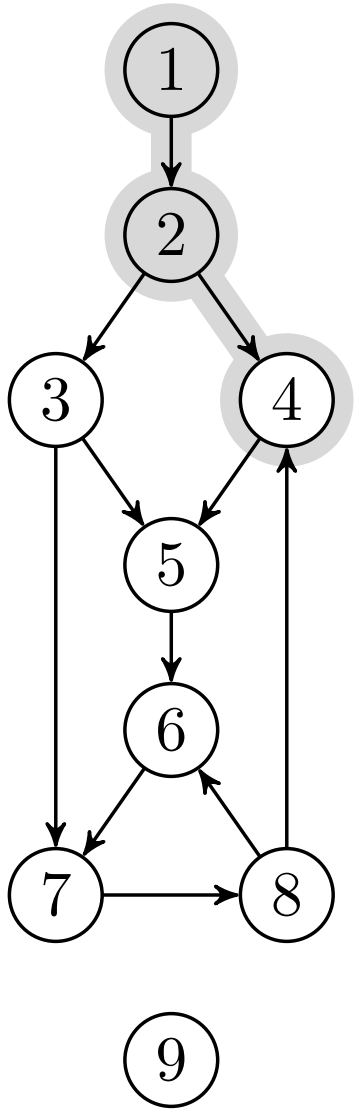

$u, v = 2, 3$





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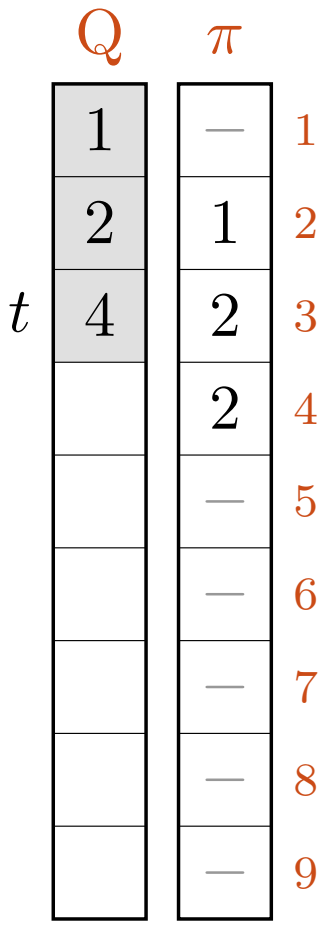

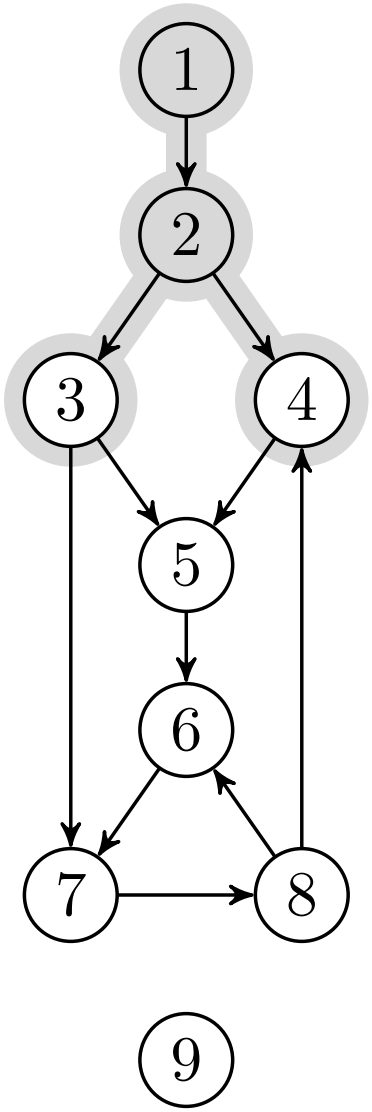

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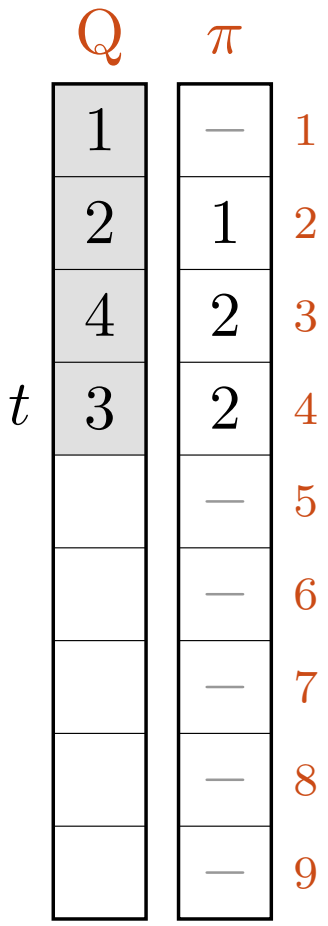
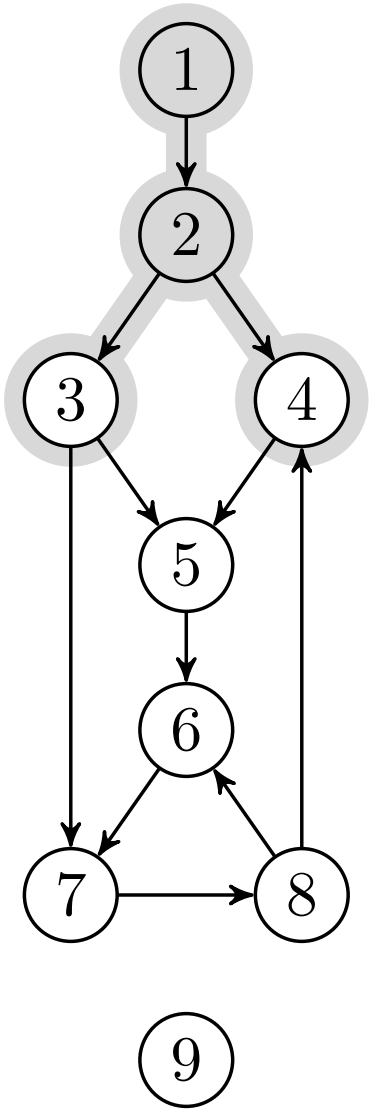
$u, v = 2, 3$





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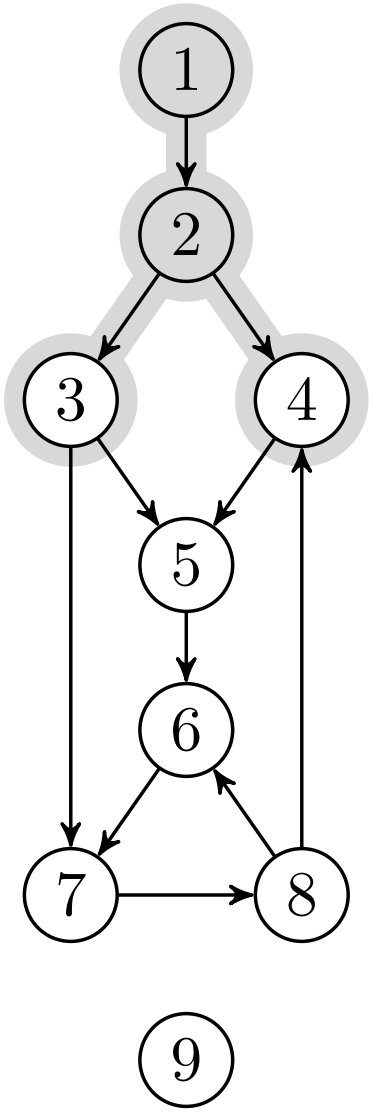
15          if v.color == WHITE
16              v.π = u
17              PUSH(Q, v)
```

$u, v = 2, 3$

t	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
		—	5
		—	6
		—	7
		—	8
		—	9



ITER-DFS-VISIT(G, s)

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12              continue
13        u.color = GRAY
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15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```
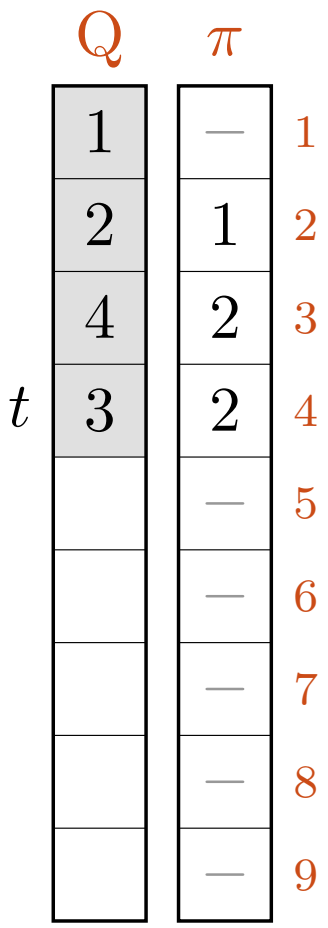
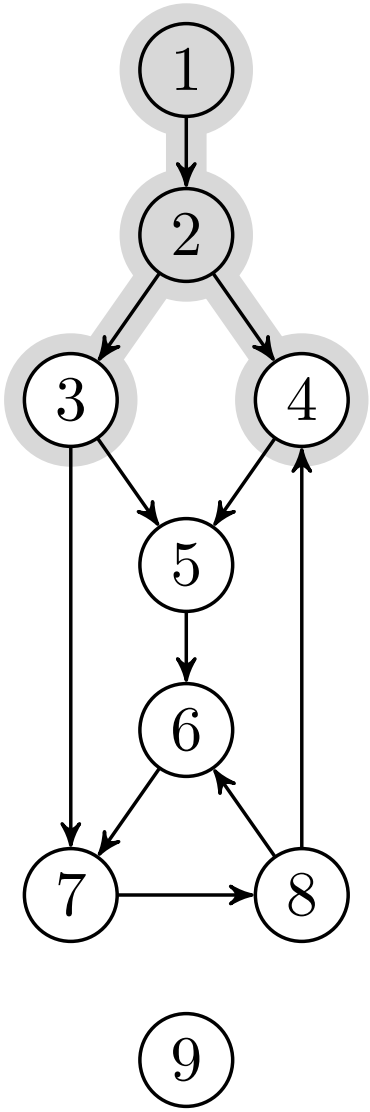

$u, v \;=\; 3, 3$





ITER-DFS-VISIT(G, s)

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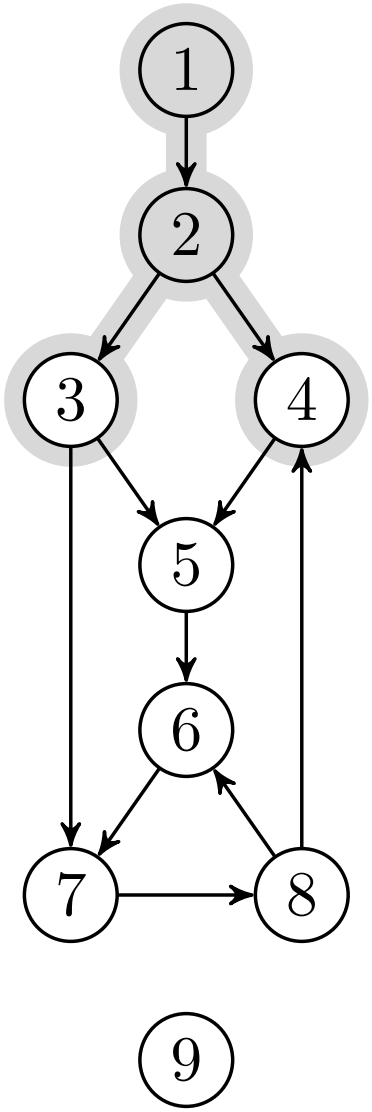
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v \;=\; 3, 3$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
t	3	2	4
		—	5
		—	6
		—	7
		—	8
		—	9



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15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```
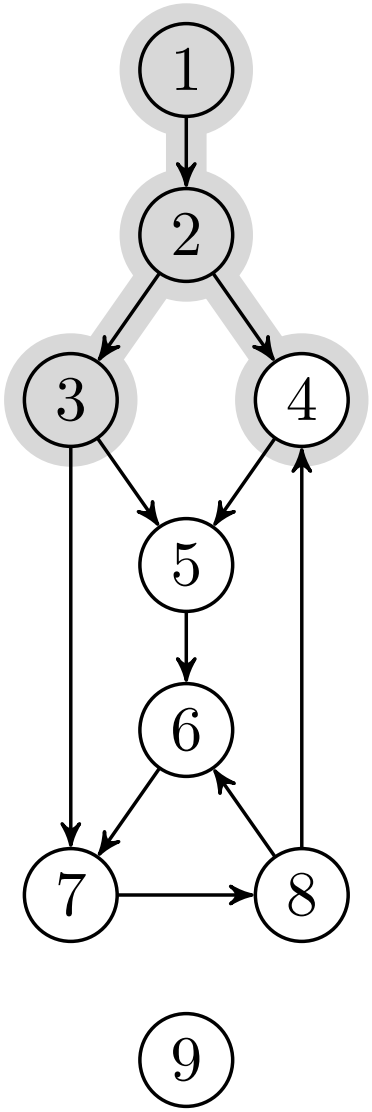

$u, v = 3, 3$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
t	3	2	4
		—	5
		—	6
		—	7
		—	8
		—	9



ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
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```
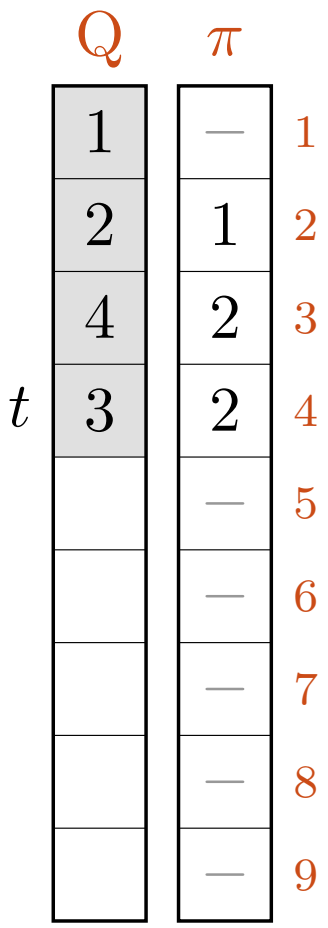
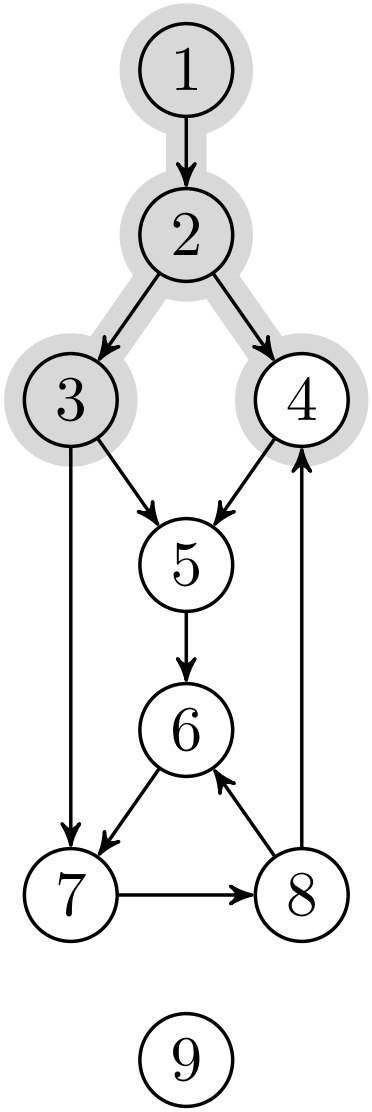

$u, v = 3, 5$





ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
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```
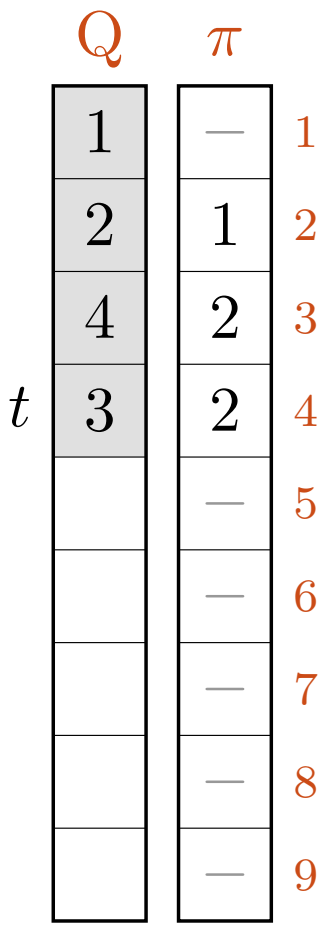
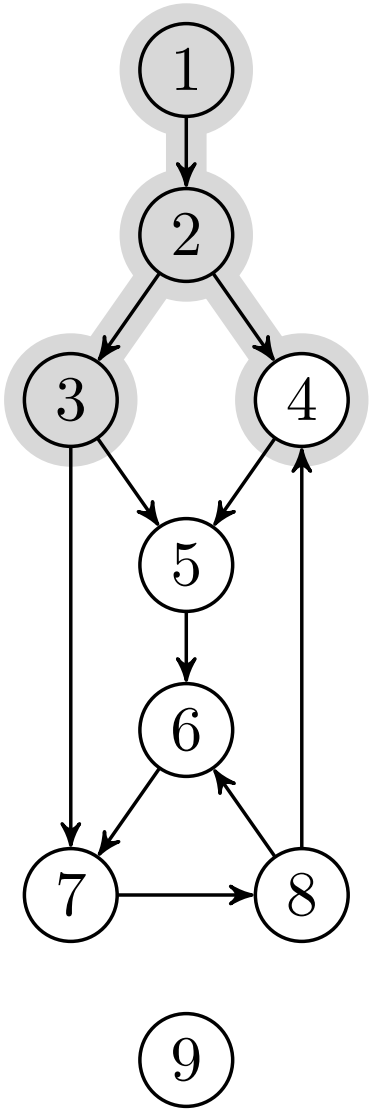

$u, v = 3, 5$



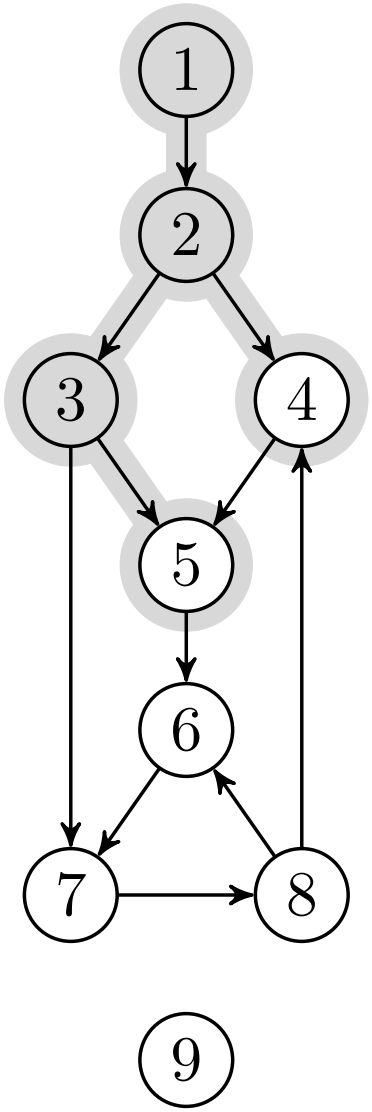


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8      u = PEEK(Q)
 9      if u.color ≠ WHITE
10          u.color = BLACK
11          POP(Q)
12          continue
13      u.color = GRAY
14      for each v ∈ G.Adj[u]
15          if v.color == WHITE
16              v.π = u
17              PUSH(Q, v)
```

$u, v = 3, 5$

t	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
		3	5
		—	6
		—	7
		—	8
		—	9



ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
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12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```
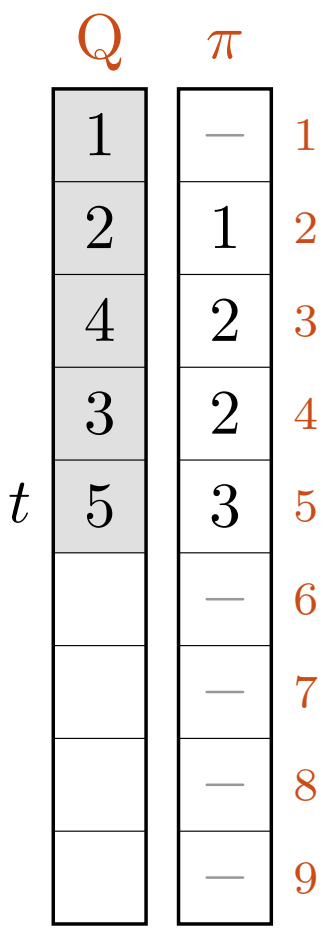
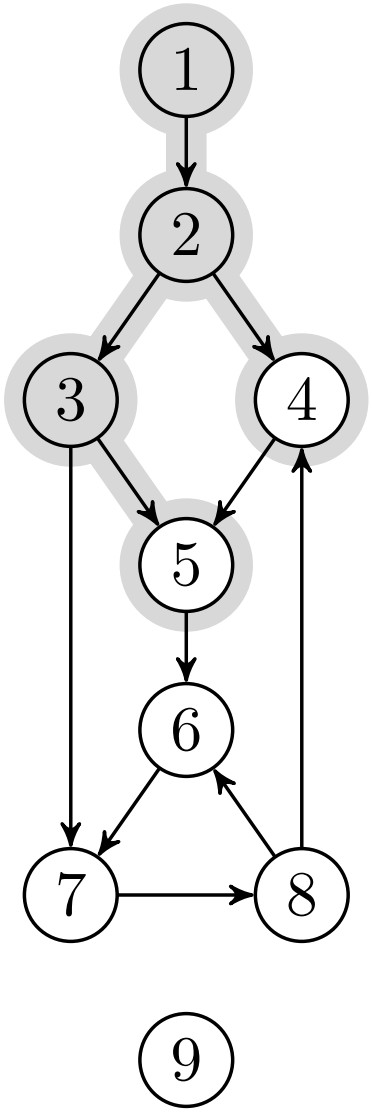

$u, v = 3, 5$



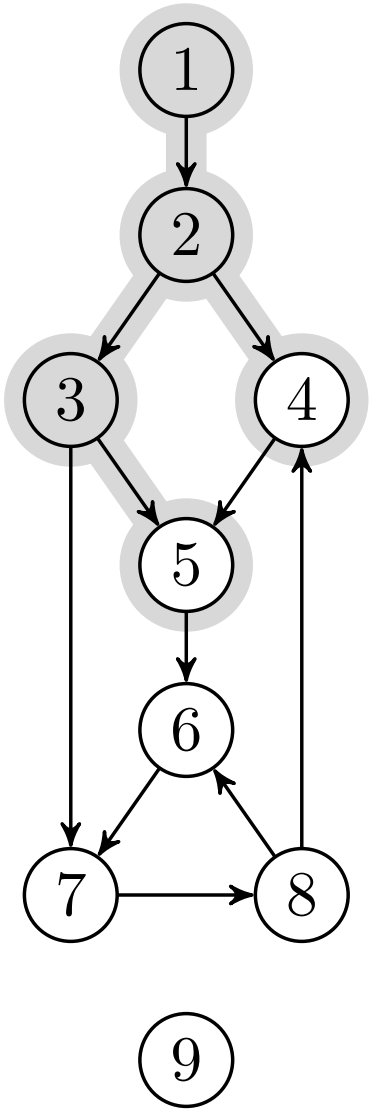


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v \;=\; 3, 7$

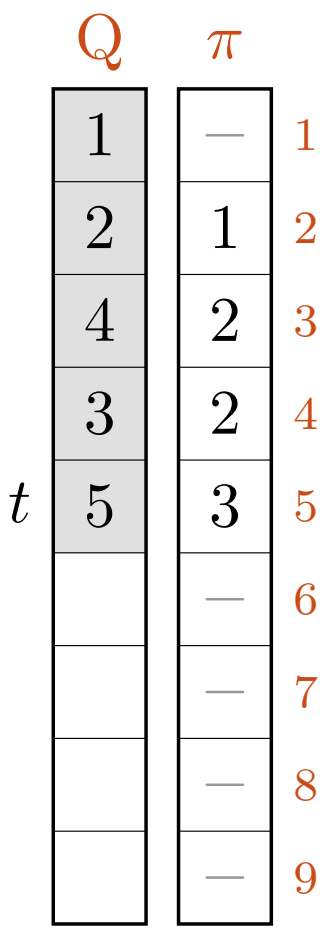
	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
t	5	3	5
		—	6
		—	7
		—	8
		—	9

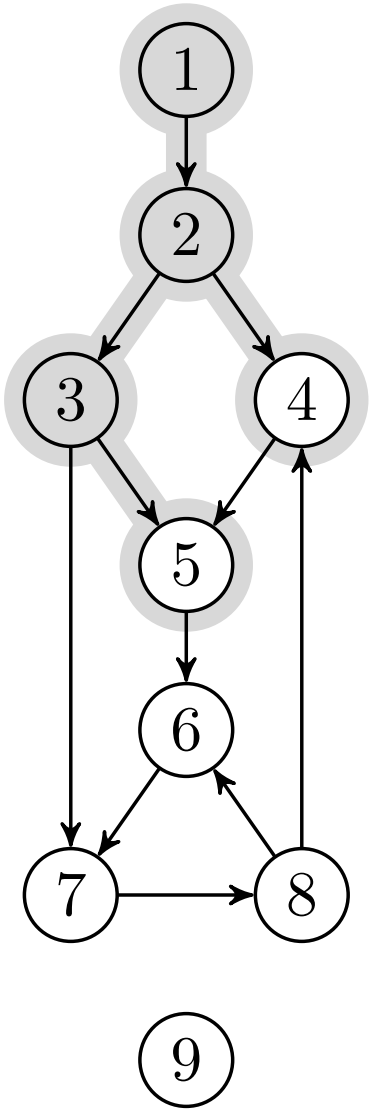


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v \;=\; 3, 7$



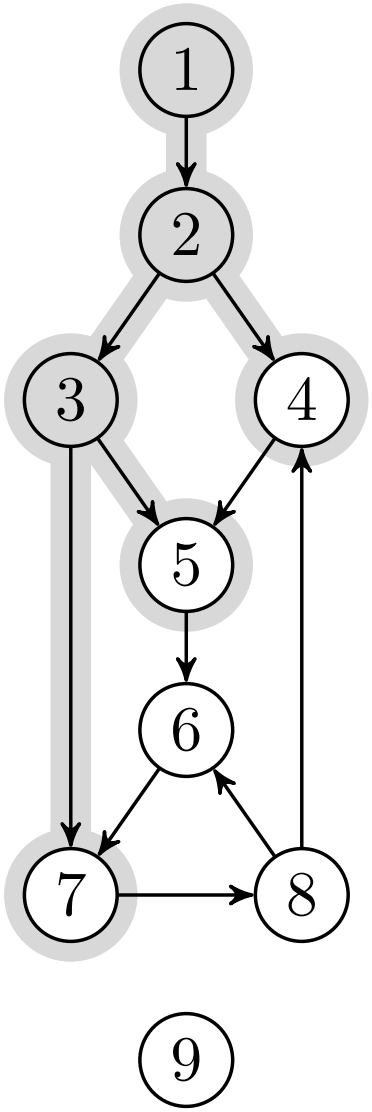


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v = 3, 7$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
t	5	3	5
		—	6
		3	7
		—	8
		—	9



ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8      u = PEEK(Q)
 9      if u.color ≠ WHITE
10          u.color = BLACK
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12          continue
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17              PUSH(Q, v)
```
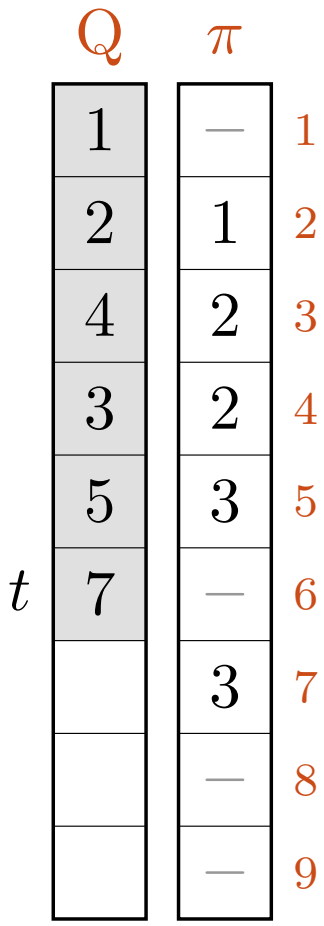
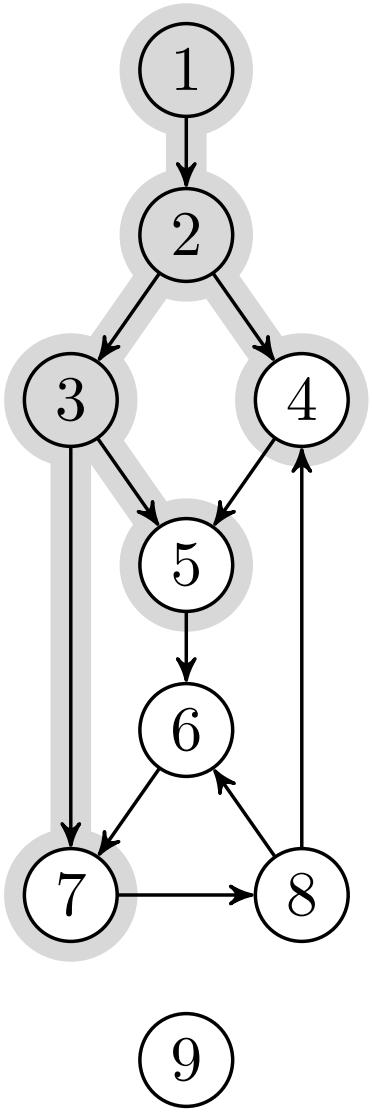

$u, v = 3, 7$





ITER-DFS-VISIT(G, s)

```
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```
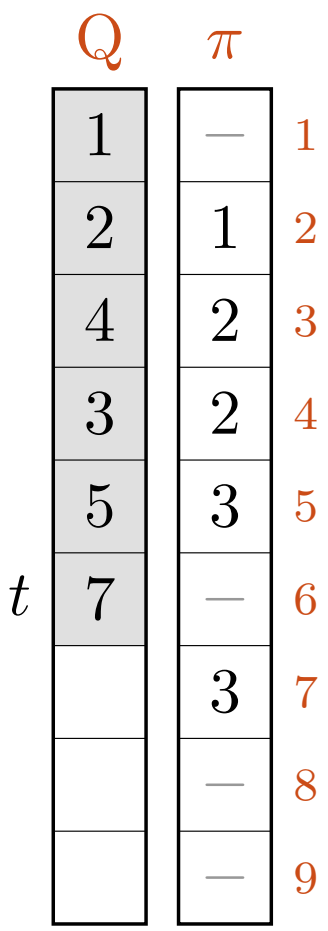
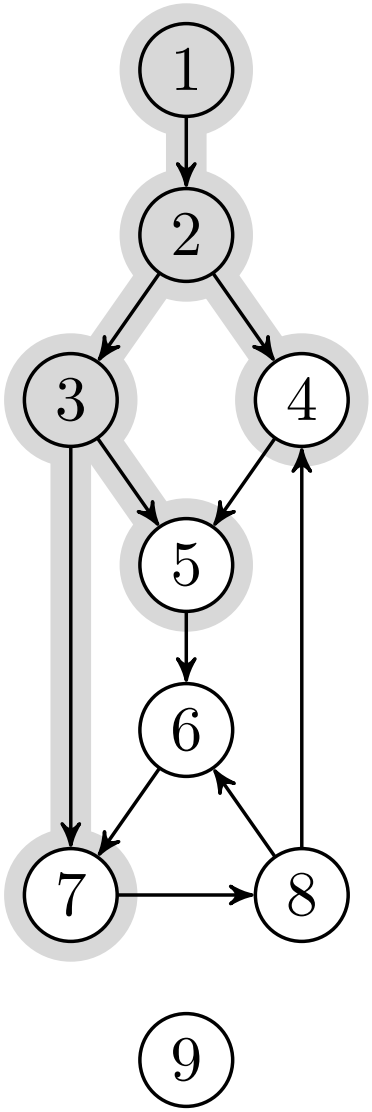

$u, v = 3, 7$





ITER-DFS-VISIT(G, s)

```
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14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```
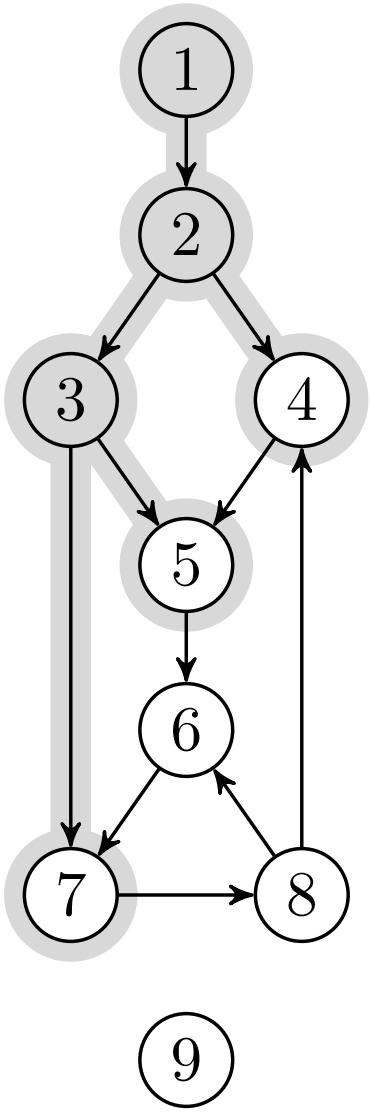

$u, v \;=\; 7, 7$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
t	7	—	6
		3	7
		—	8
		—	9



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```
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16                    v.π = u
17                    PUSH(Q, v)
```
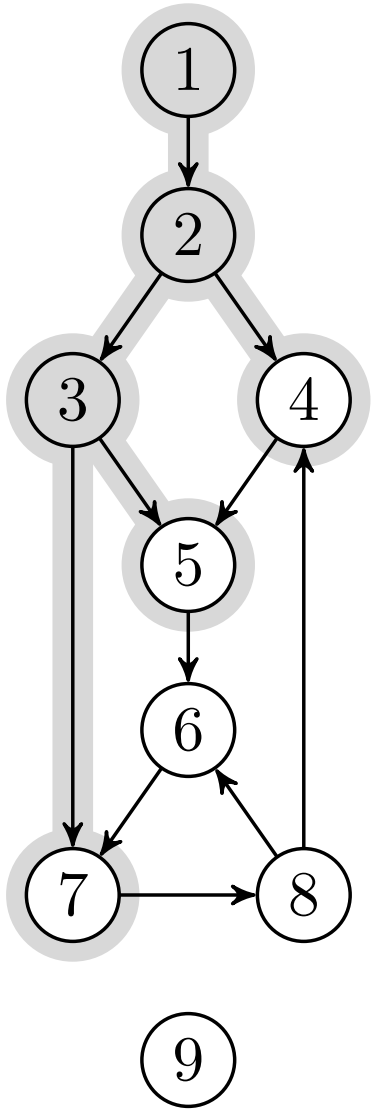

$u, v \;=\; 7, 7$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
t	7	—	6
		3	7
		—	8
		—	9



ITER-DFS-VISIT(G, s)

```
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```
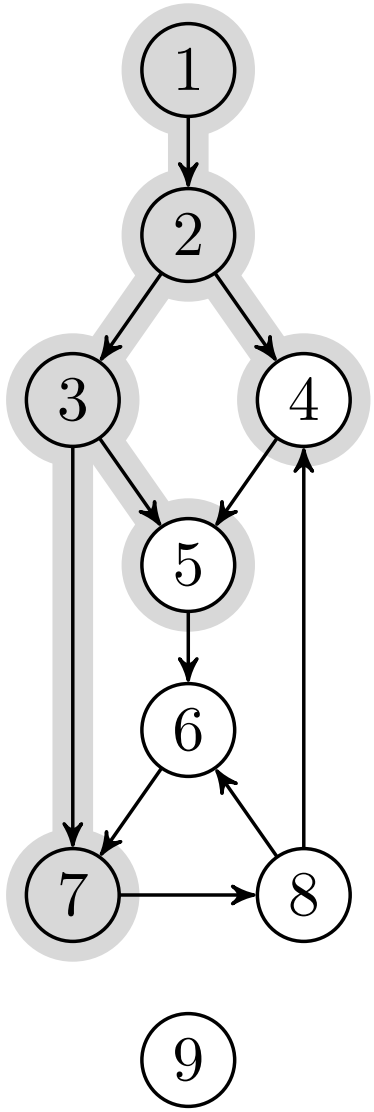

$u, v \;=\; 7, 7$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
t	7	—	6
		3	7
		—	8
		—	9



ITER-DFS-VISIT(G, s)

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 8        u = PEEK(Q)
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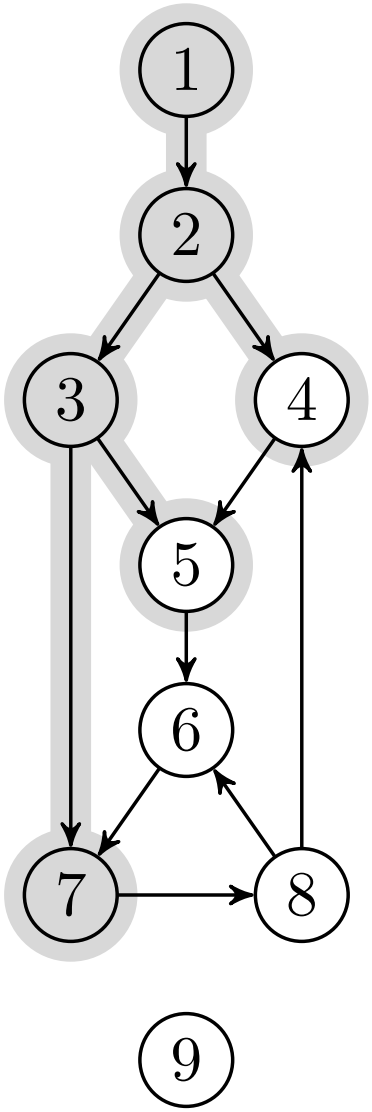
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v = 7, 8$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
t	7	—	6
		3	7
		—	8
		—	9



ITER-DFS-VISIT(G, s)

```
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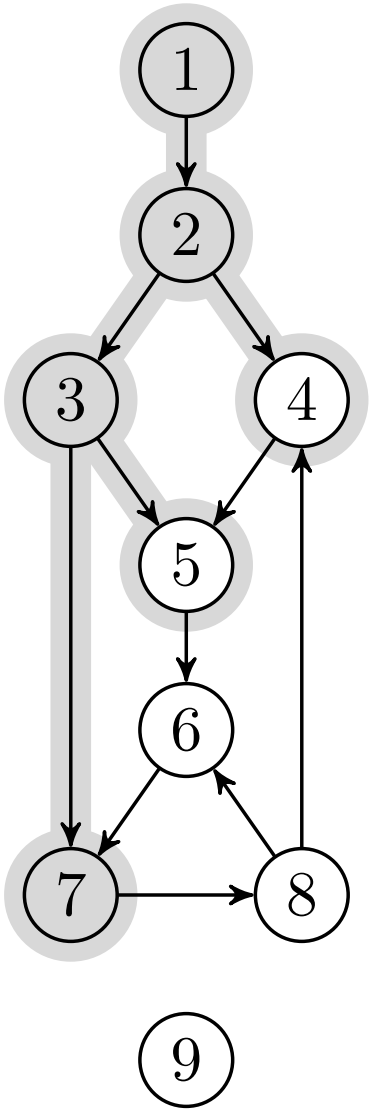
$u, v = 7, 8$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
t	7	—	6
		3	7
		—	8
		—	9



ITER-DFS-VISIT(G, s)

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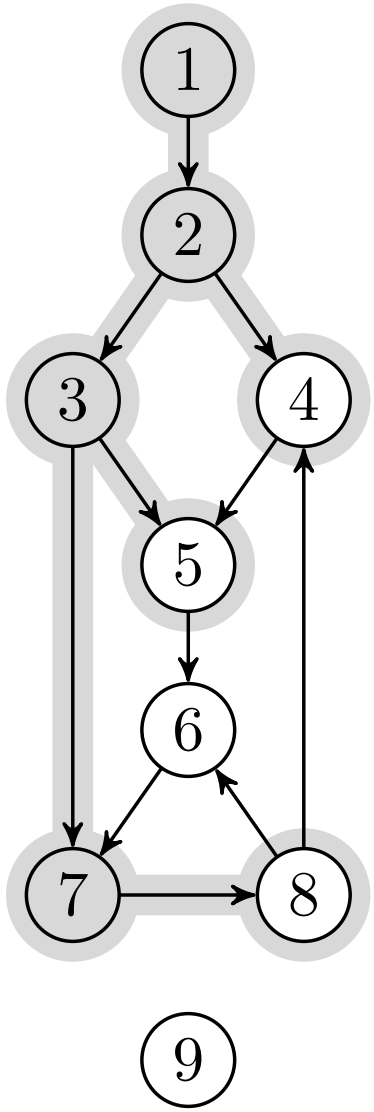
$u, v = 7, 8$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
t	7	—	6
		3	7
		7	8
		—	9



ITER-DFS-VISIT(G, s)

```
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17              PUSH(Q, v)
```
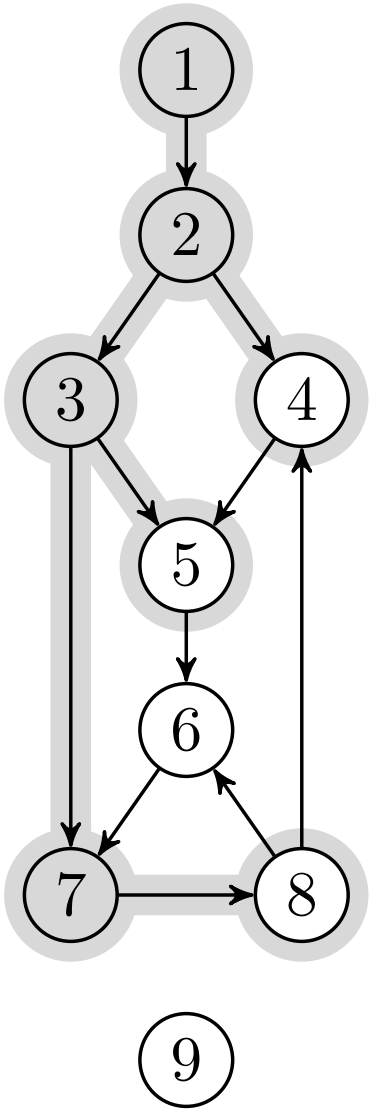

$u, v = 7, 8$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
	7	—	6
t	8	3	7
		7	8
		—	9



ITER-DFS-VISIT(G, s)

```
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 7  while Q ≠ ∅
 8      u = PEEK(Q)
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11          POP(Q)
12          continue
13      u.color = GRAY
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15          if v.color == WHITE
16              v.π = u
17              PUSH(Q, v)
```
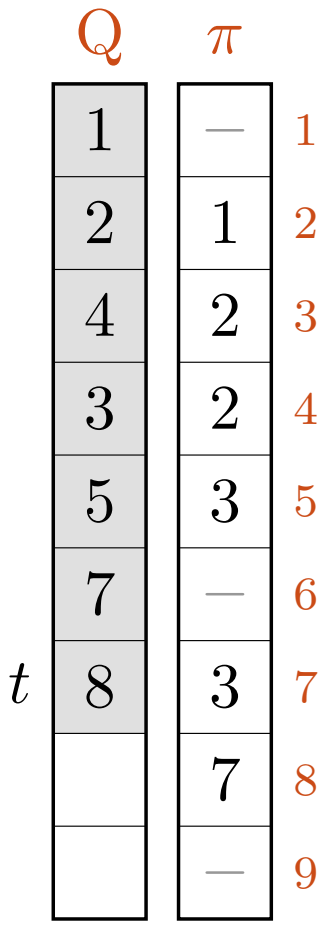
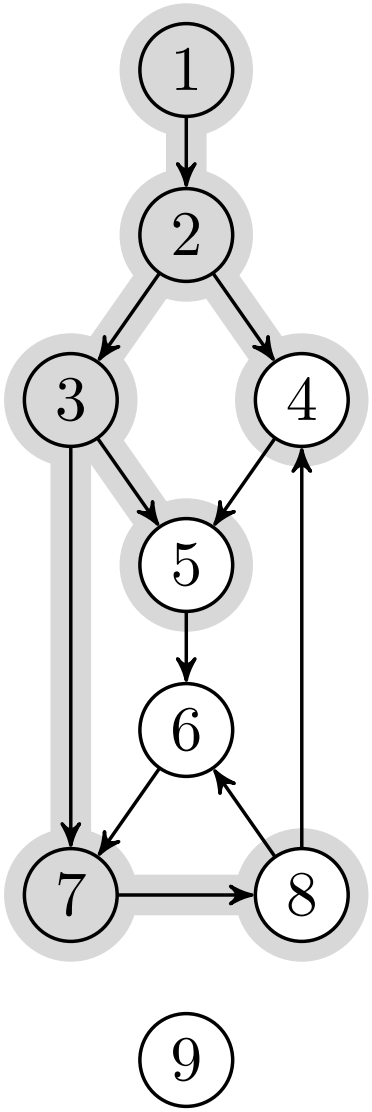

$u, v = 7, 8$





ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
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11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```
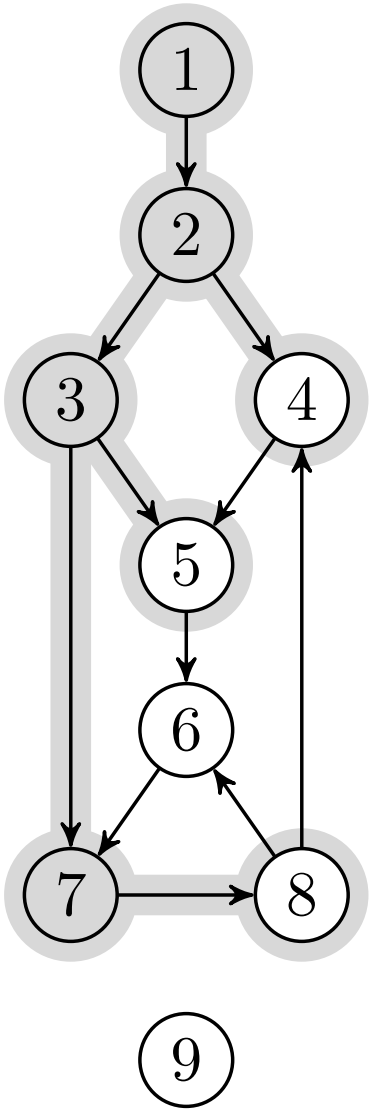

$u, v \;=\; 8, 8$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
	7	—	6
t	8	3	7
		7	8
		—	9

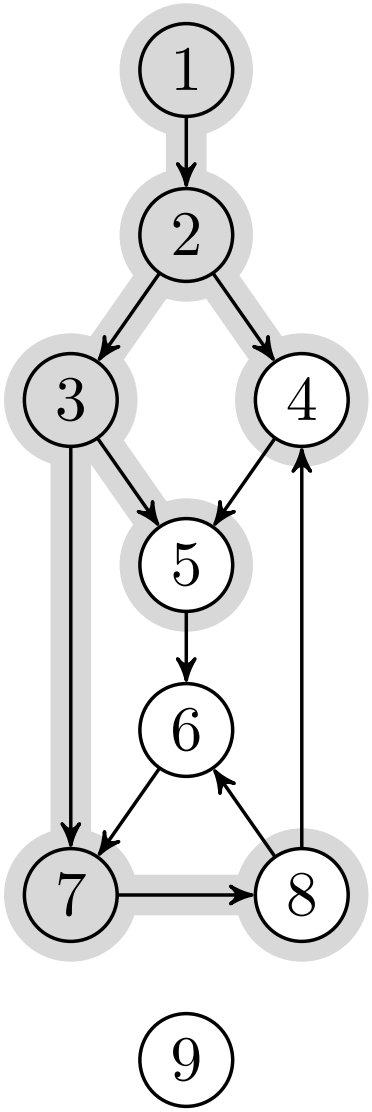


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v = 8, 8$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
	7	—	6
t	8	3	7
		7	8
		—	9



ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
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10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```
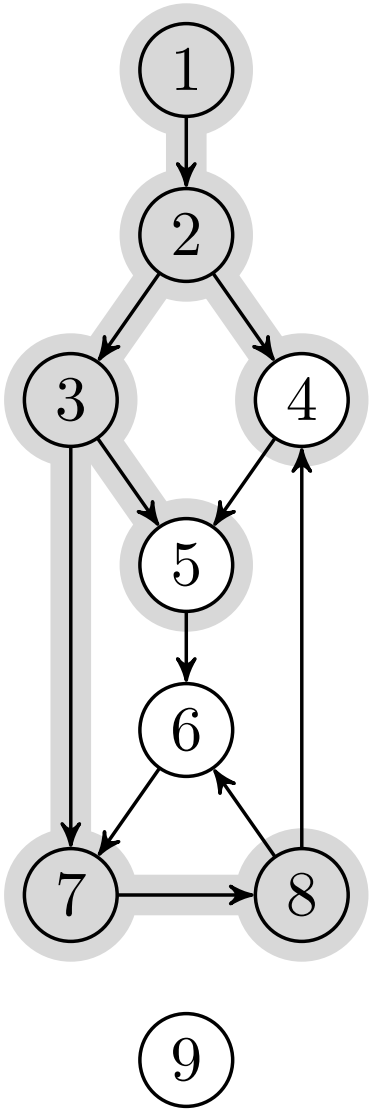

$u, v = 8, 8$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
	7	—	6
t	8	3	7
		7	8
		—	9

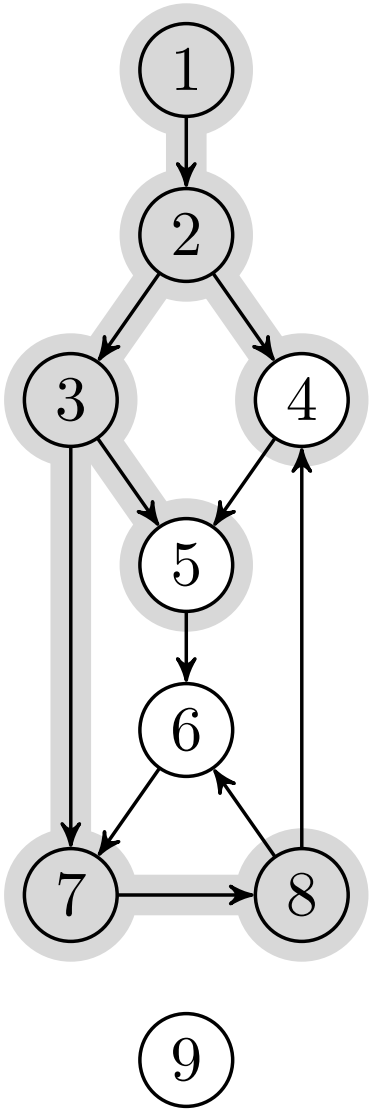


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v = 8, 4$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
	7	—	6
t	8	3	7
		7	8
		—	9

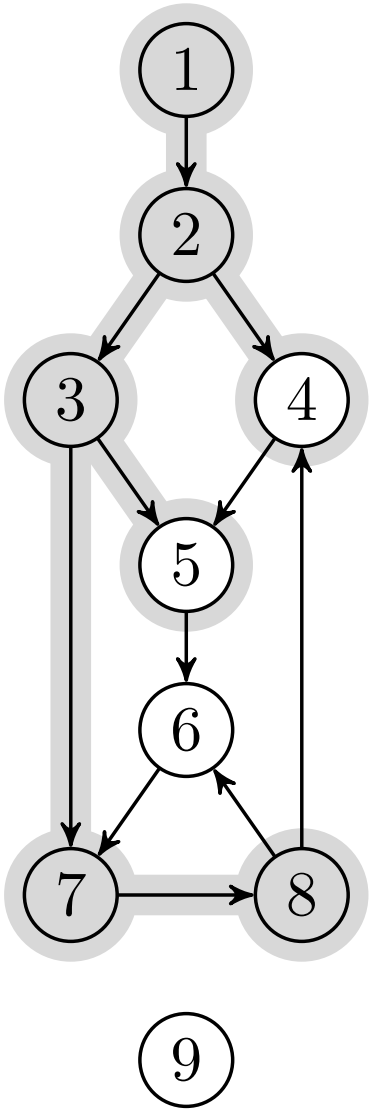


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v = 8, 4$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	2	4
	5	3	5
	7	—	6
t	8	3	7
		7	8
		—	9

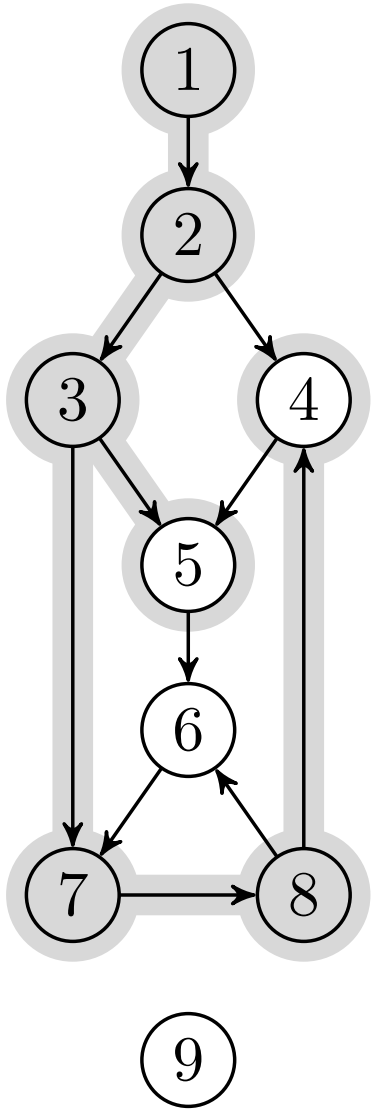


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v \;=\; 8, 4$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	3	5
	7	—	6
t	8	3	7
		7	8
		—	9

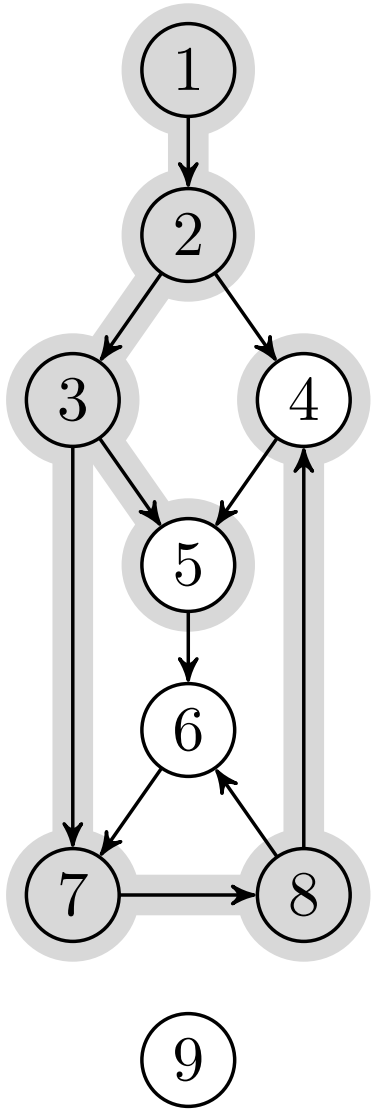


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8        u = PEEK(Q)
 9        if u.color ≠ WHITE
10              u.color = BLACK
11              POP(Q)
12              continue
13        u.color = GRAY
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v = 8, 4$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	3	5
	7	—	6
	8	3	7
t	4	7	8
		—	9



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$u, v = 8, 6$

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	2	1	2
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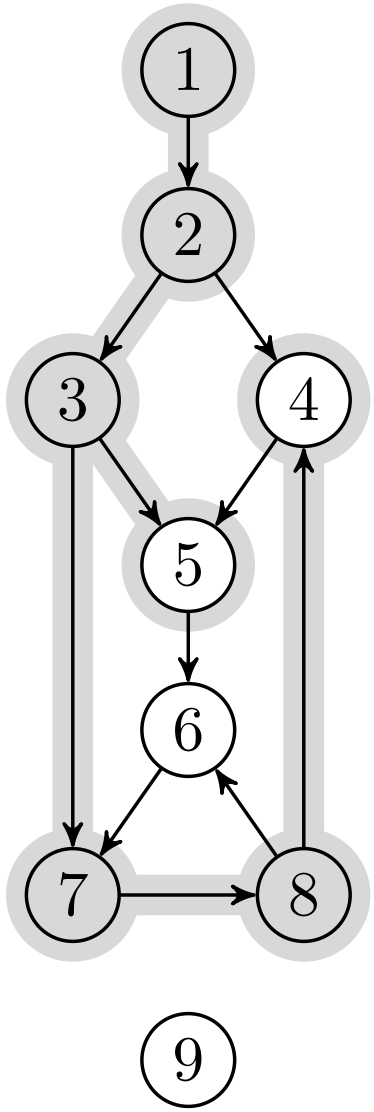
	3	8	4
	5	3	5
	7	—	6
	8	3	7
t	4	7	8
		—	9



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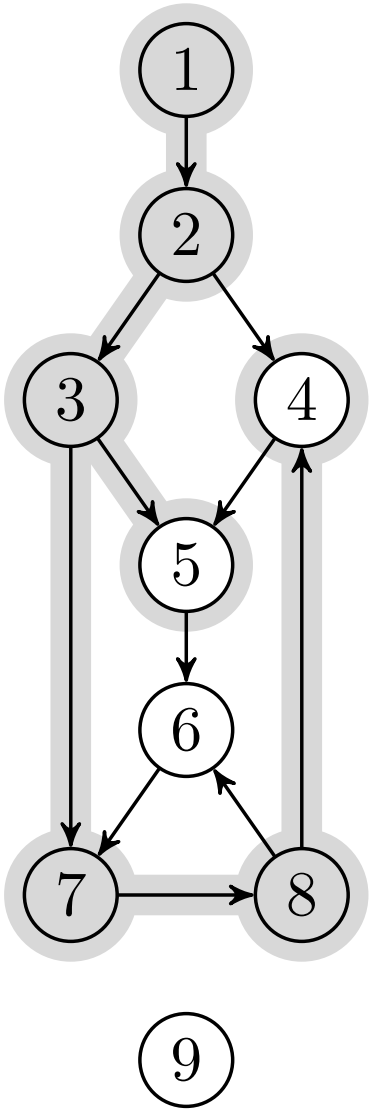

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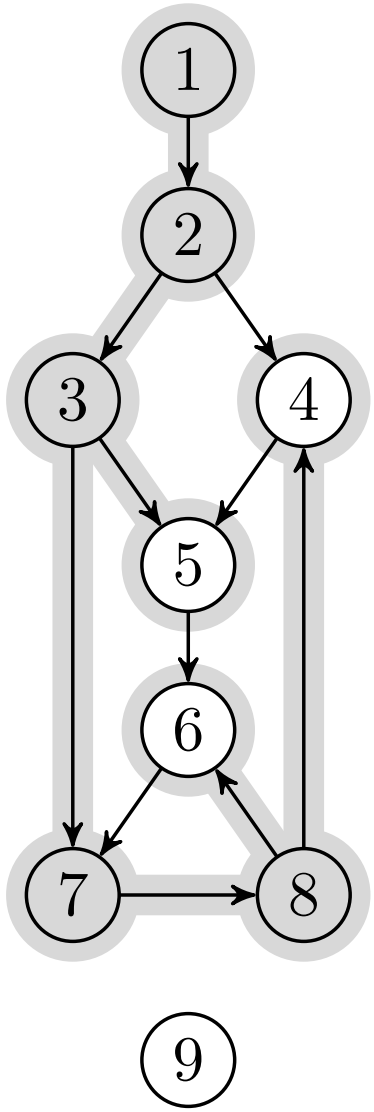

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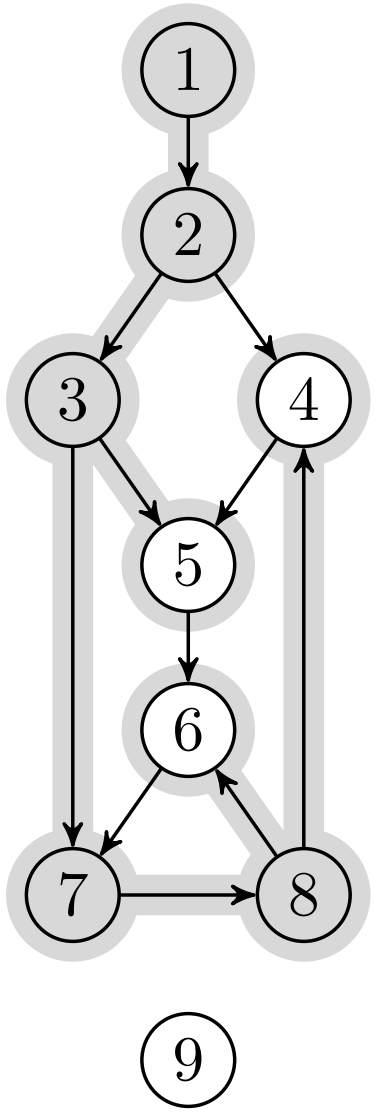

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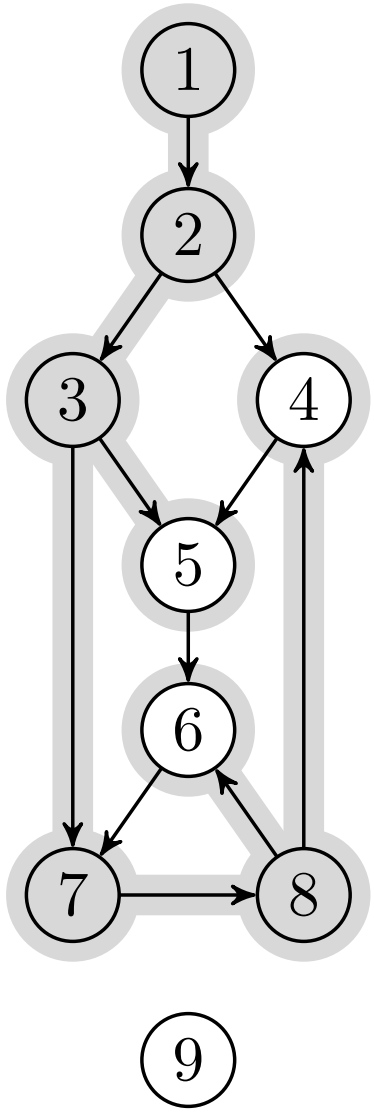

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$u, v \;=\; 6, 6$

	Q	π	
	1	—	1
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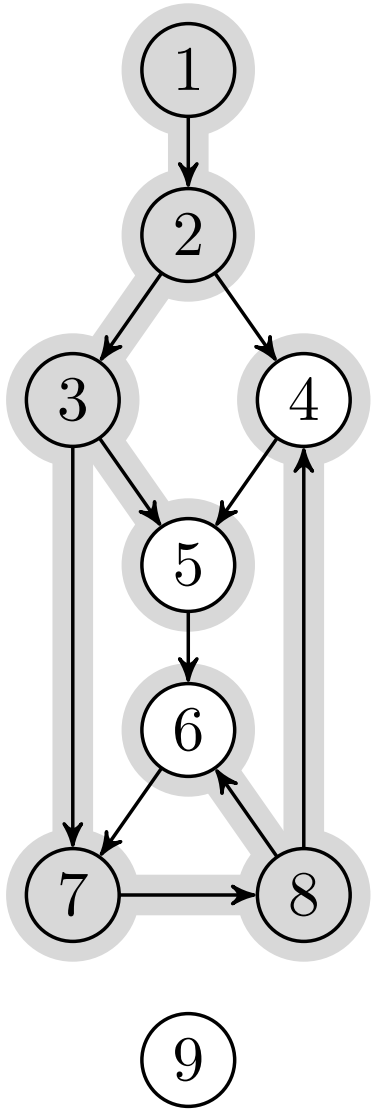

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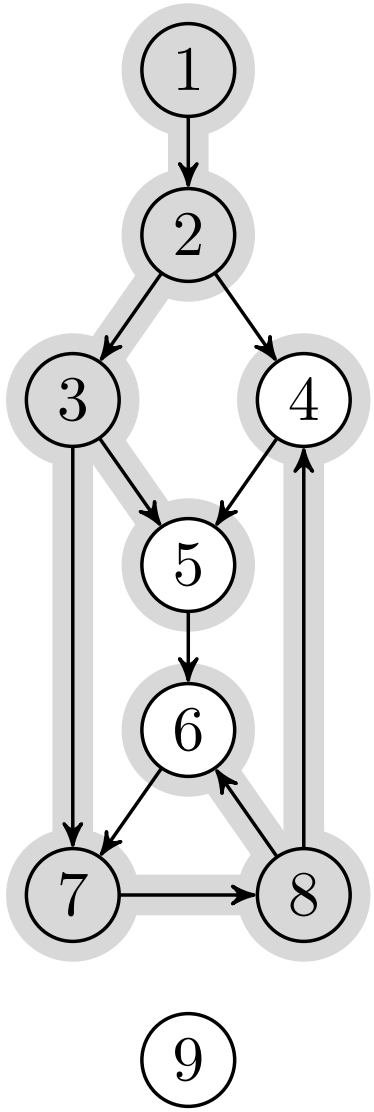

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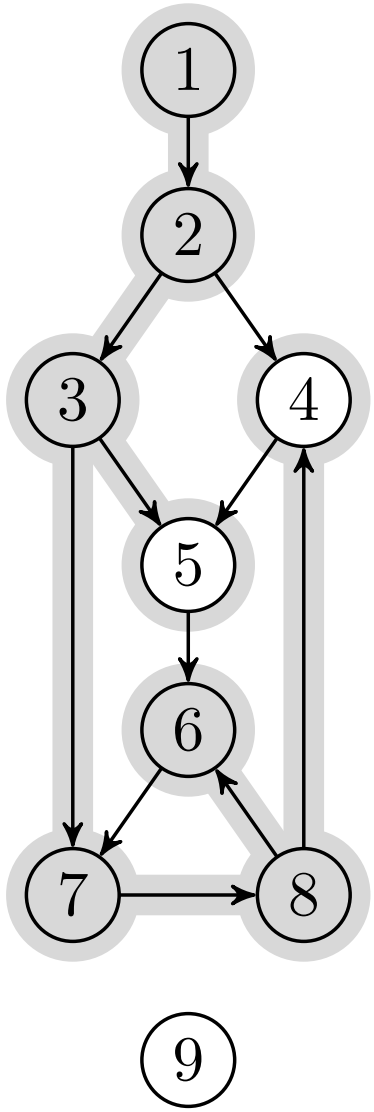

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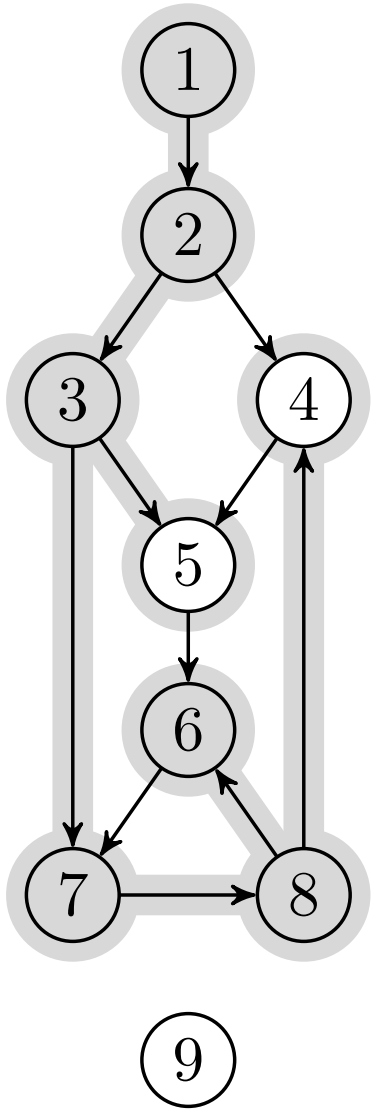

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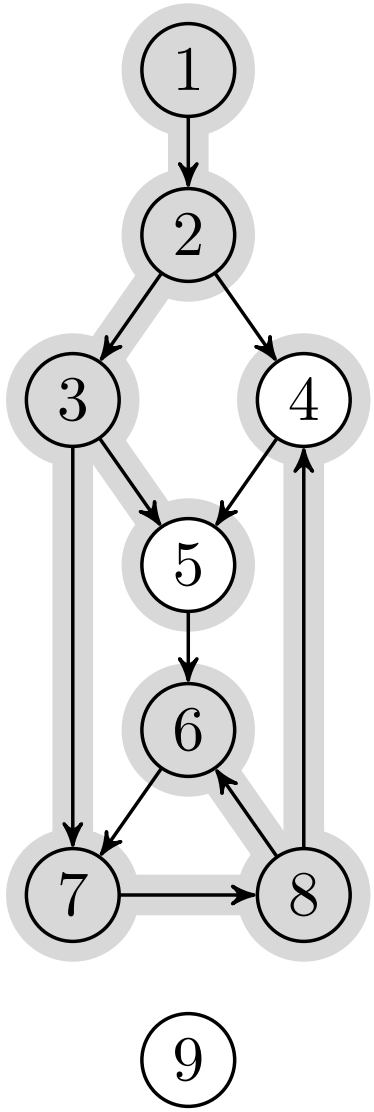

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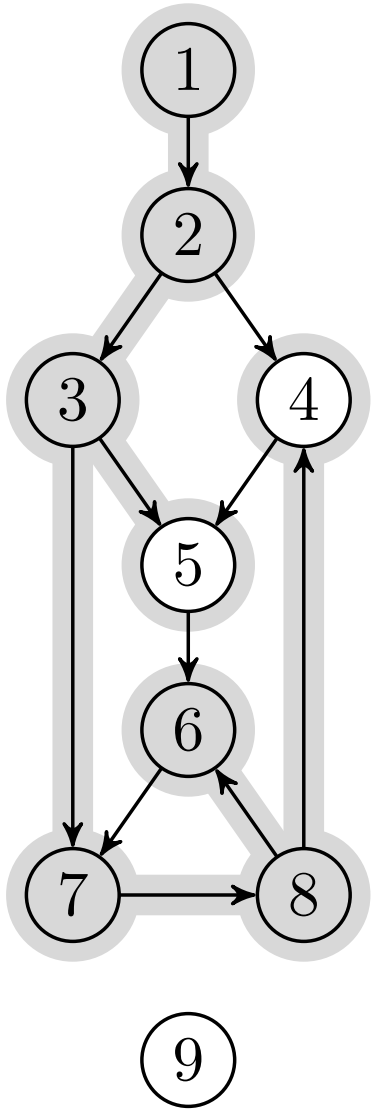

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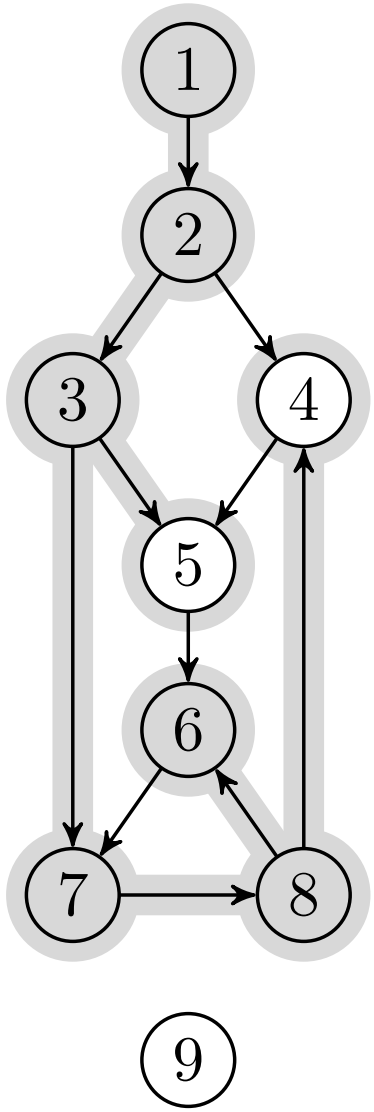

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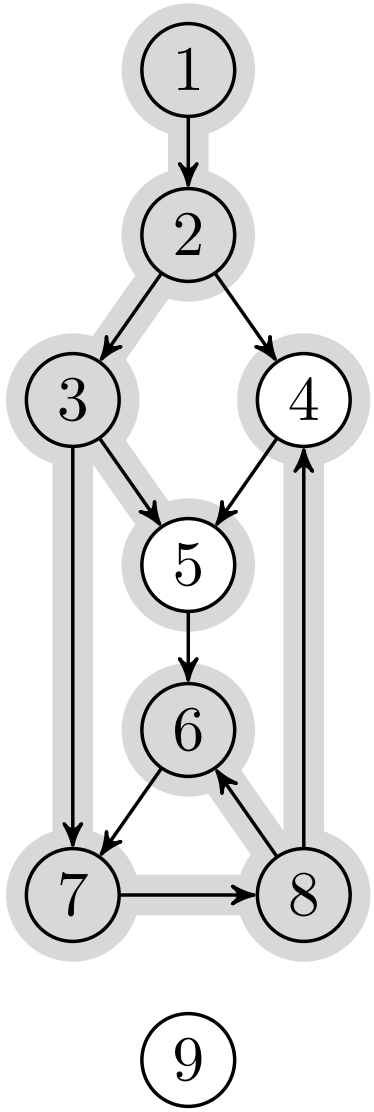

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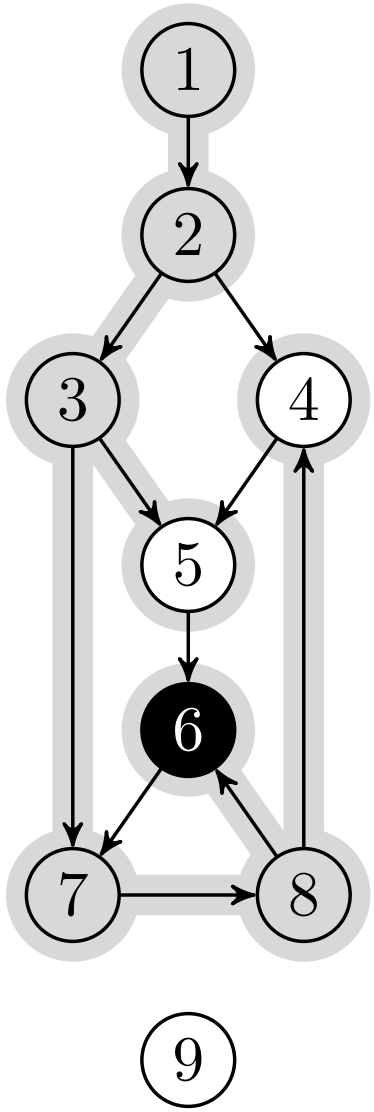

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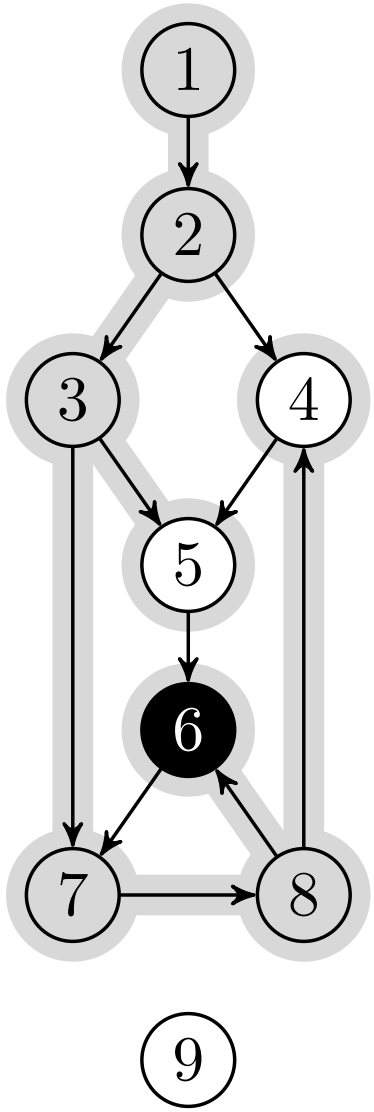

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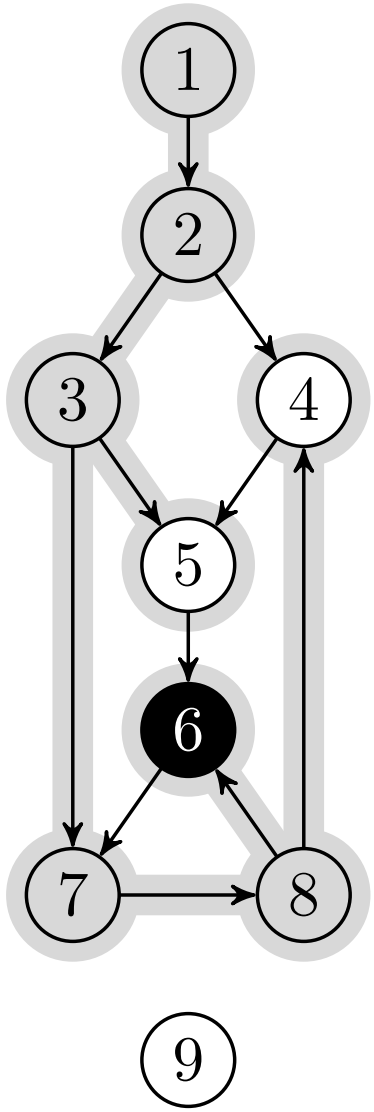

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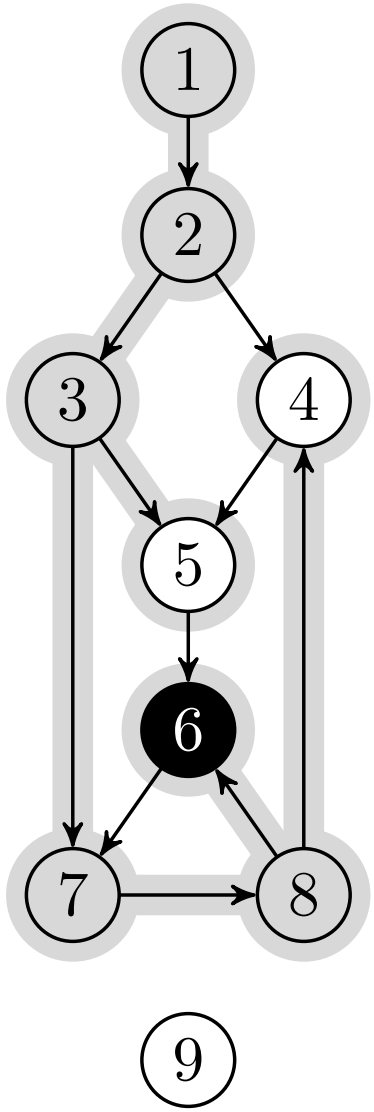

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```

$u, v \;=\; 4, 7$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	3	5
	7	8	6
	8	3	7
t	4	7	8
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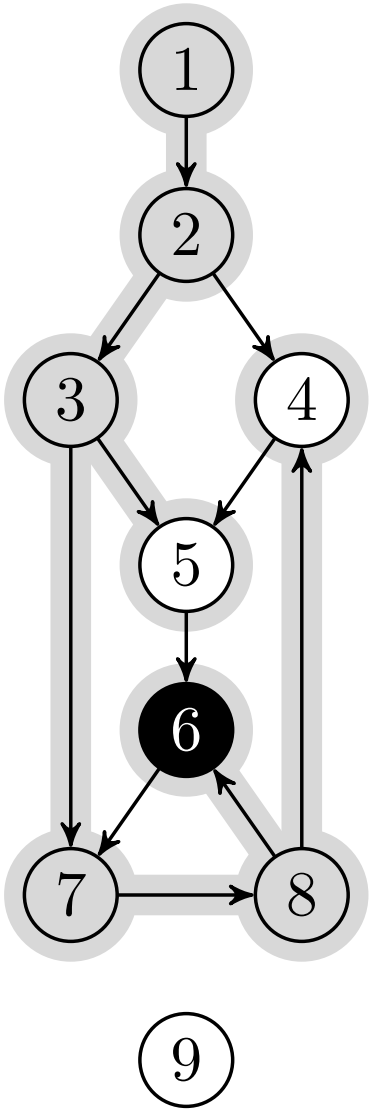

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$u, v = 4, 7$

	Q	π	
	1	—	1
	2	1	2
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	3	8	4
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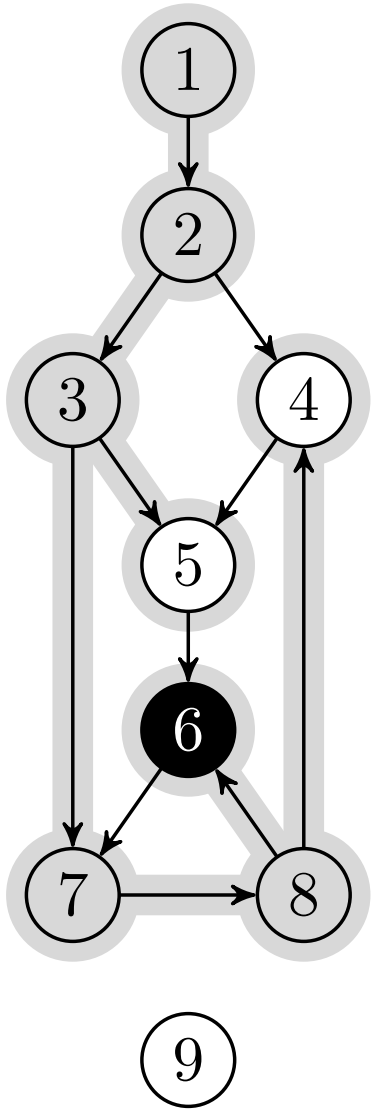

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$u, v \;=\; 4, 7$

	Q	π	
	1	—	1
	2	1	2
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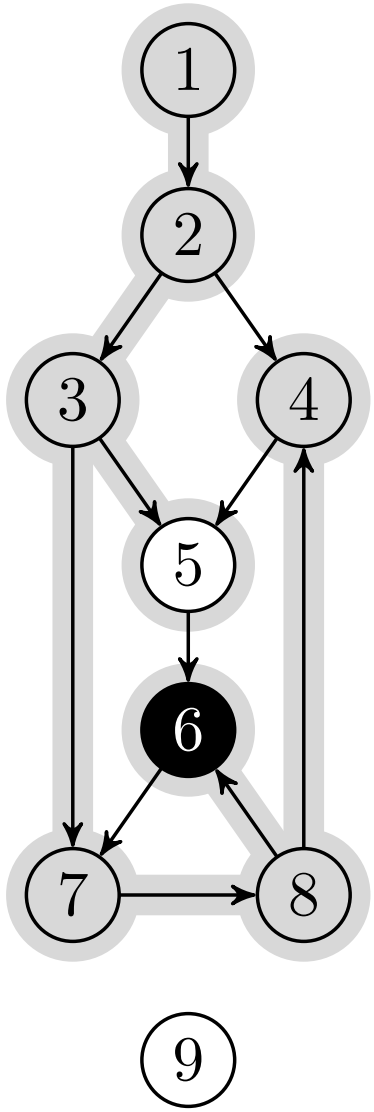

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```
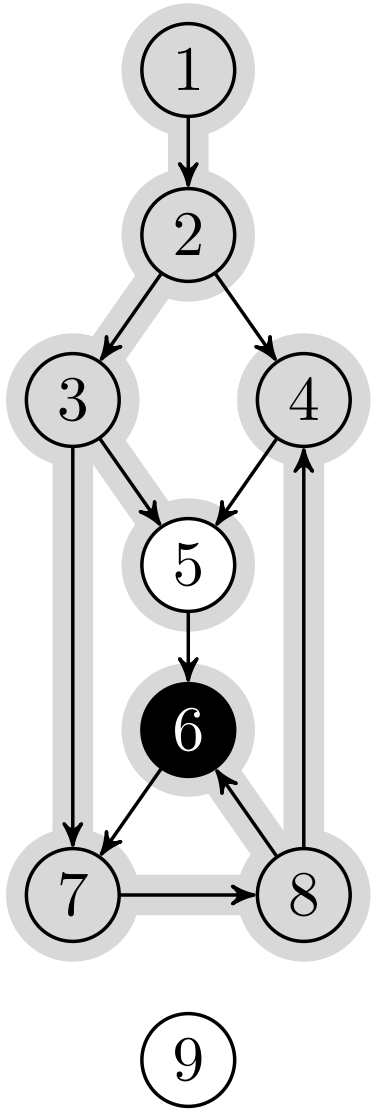

$u, v \;=\; 4, 5$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	3	5
	7	8	6
	8	3	7
t	4	7	8
	6	—	9



ITER-DFS-VISIT(G, s)

```
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```

$u, v = 4, 5$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
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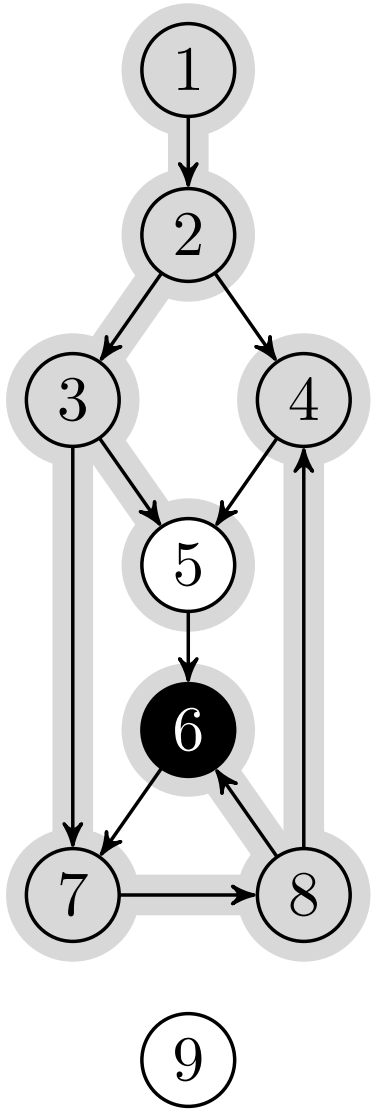

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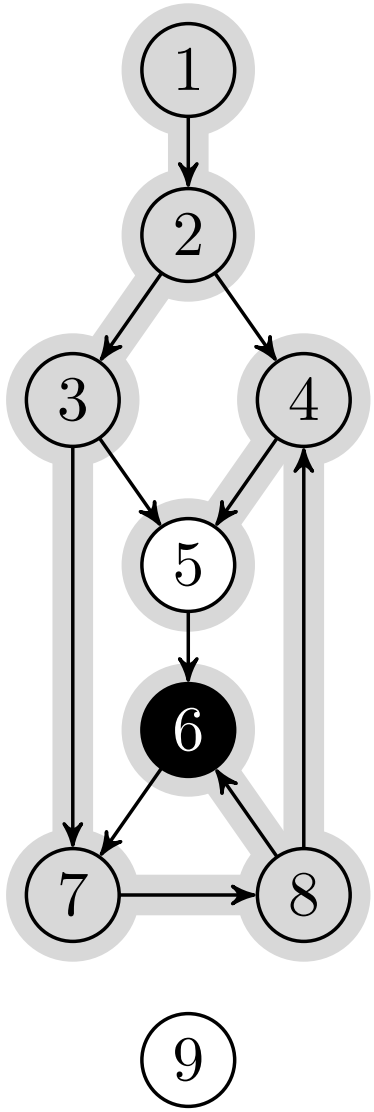
$u, v = 4, 5$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
t	4	7	8
	6	—	9

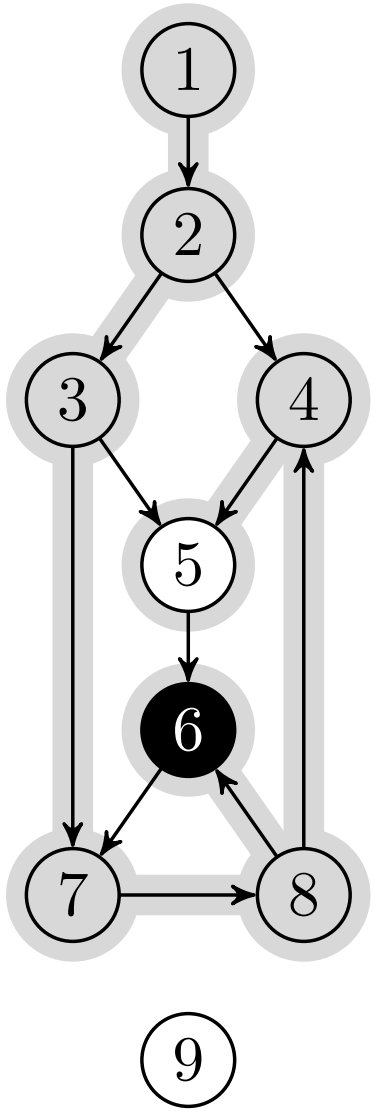


ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
 8      u = PEEK(Q)
 9      if u.color ≠ WHITE
10          u.color = BLACK
11          POP(Q)
12          continue
13      u.color = GRAY
14      for each v ∈ G.Adj[u]
15          if v.color == WHITE
16              v.π = u
17              PUSH(Q, v)
```

$u, v = 4, 5$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
	4	7	8
t	5	—	9



ITER-DFS-VISIT(G, s)

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 6  ...
 7  while Q ≠ ∅
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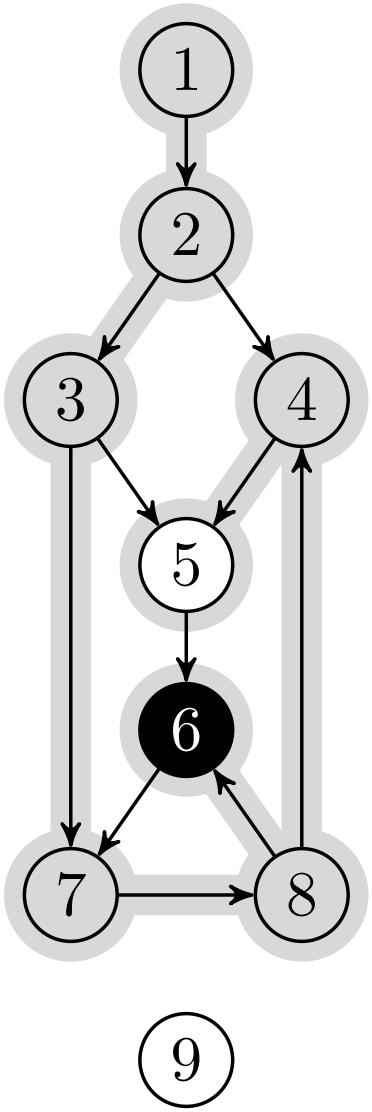
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v \;=\; 4, 5$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
	4	7	8
t	5	—	9



ITER-DFS-VISIT(G, s)

```
 6  ...
 7  while Q ≠ ∅
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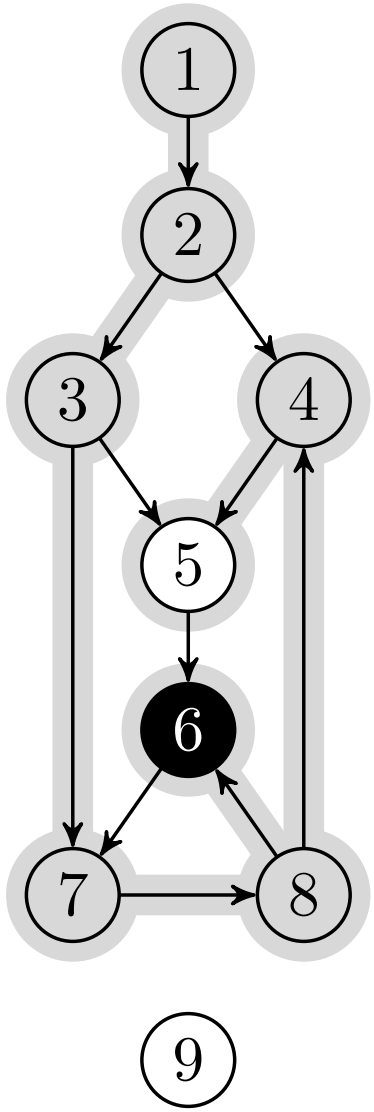
14        for each v ∈ G.Adj[u]
15              if v.color == WHITE
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v \;=\; 5, 5$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
	4	7	8
t	5	—	9



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17                    PUSH(Q, v)
```
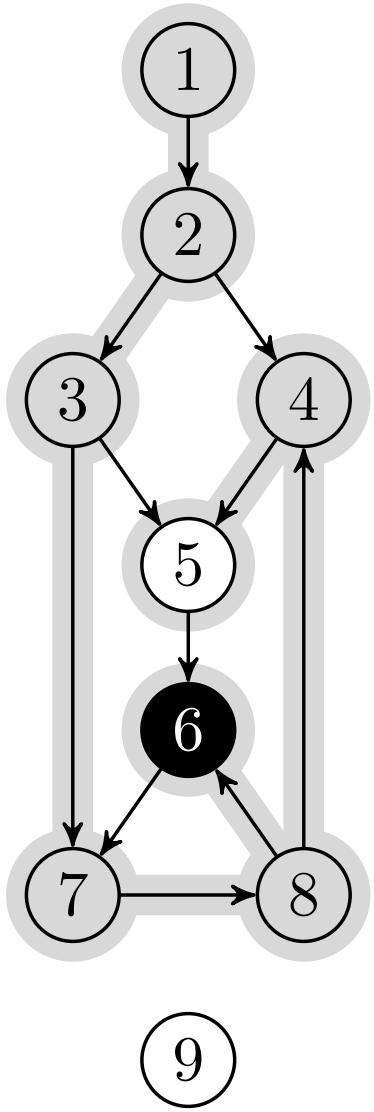

$u, v \;=\; 5, 5$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
	4	7	8
t	5	—	9



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```

$u, v \;=\; 5, 5$

	Q	π	
	1	—	1
	2	1	2
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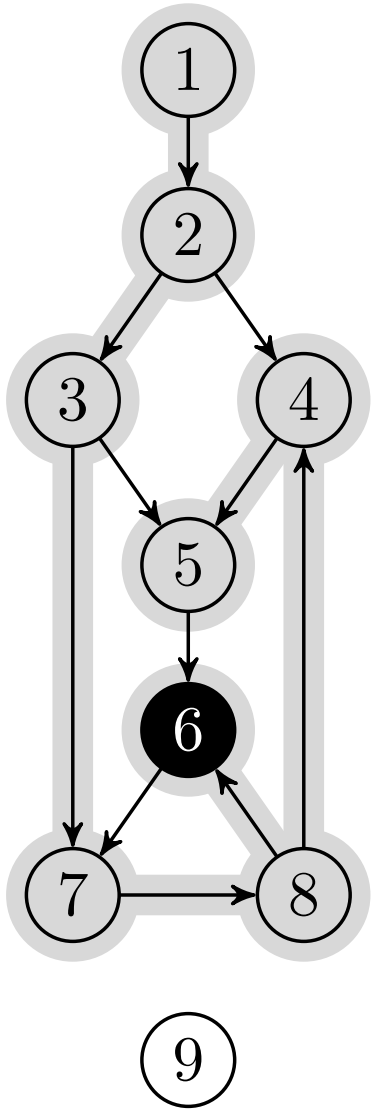
	3	8	4
	5	4	5
	7	8	6
	8	3	7
	4	7	8
t	5	—	9



ITER-DFS-VISIT(G, s)

```
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 7  while Q ≠ ∅
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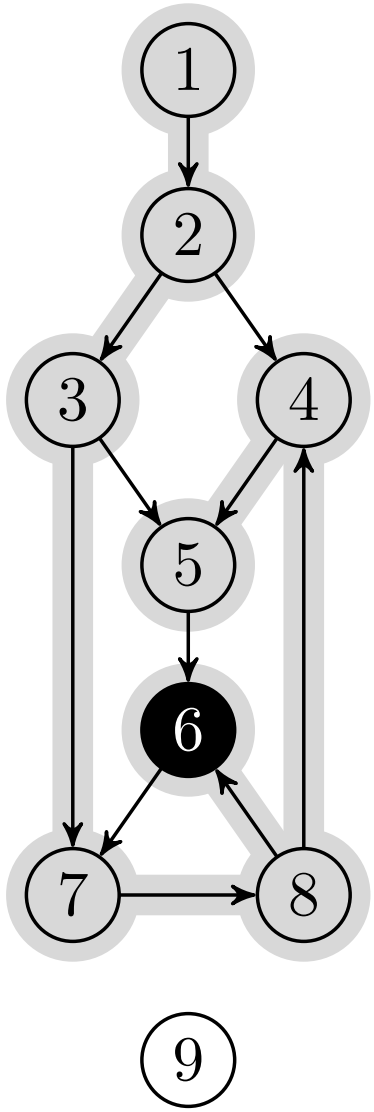
16                    v.π = u
17                    PUSH(Q, v)
```

$u, v \;=\; 5, 6$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
	4	7	8
t	5	—	9



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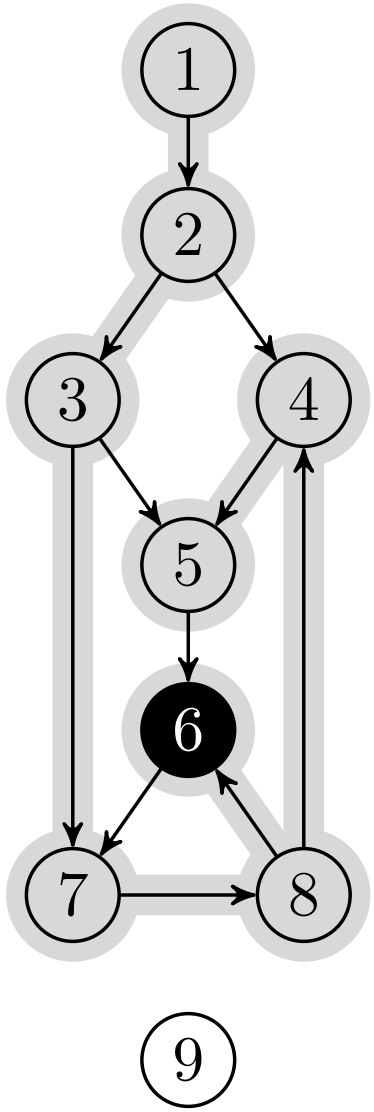
$u, v = 5, 6$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
	4	7	8
t	5	—	9



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	Q	π	
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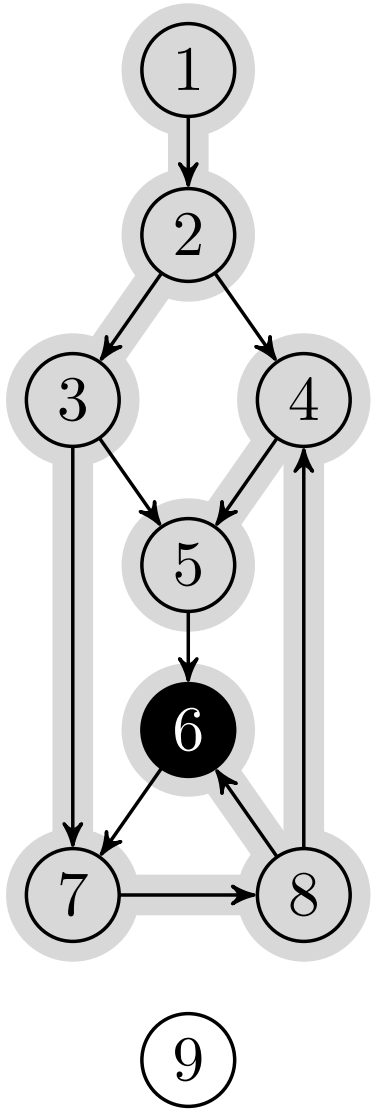
	7	8	6
	8	3	7
	4	7	8
t	5	—	9



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	1	—	1
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	7	8	6
	8	3	7
	4	7	8
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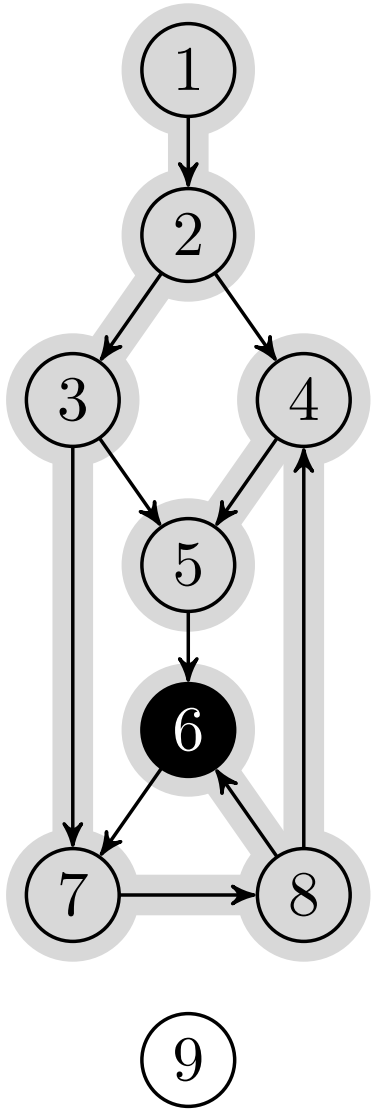

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	7	8	6
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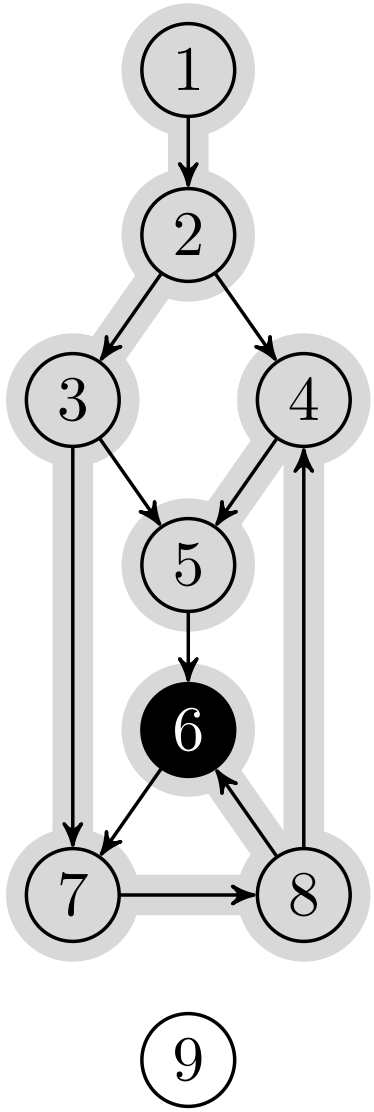

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	7	8	6
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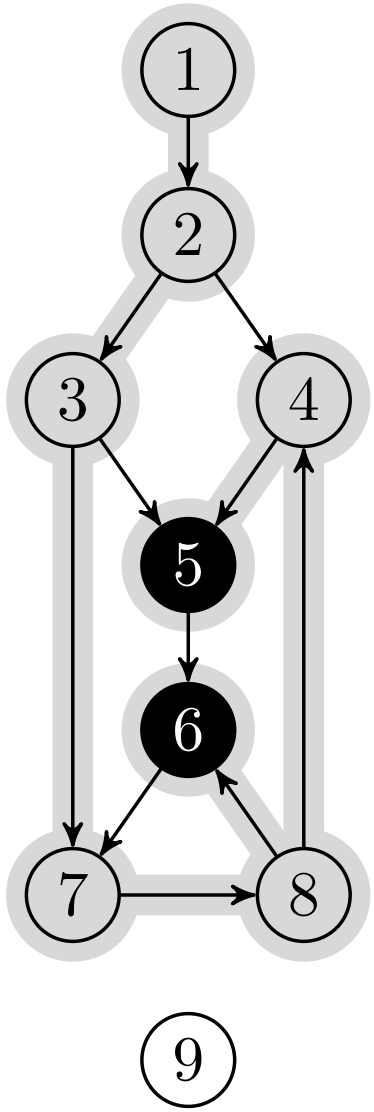

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$u, v = 5, 6$

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	5	4	5
	7	8	6
	8	3	7
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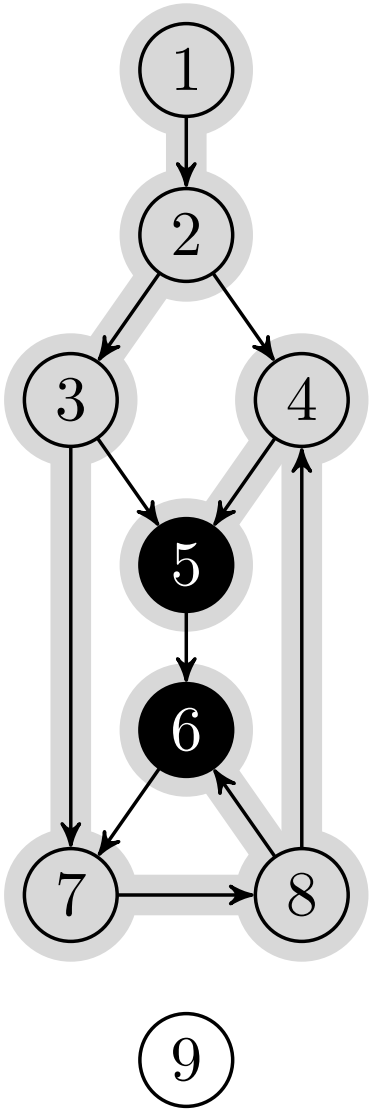
	5	—	9



ITER-DFS-VISIT(G, s)

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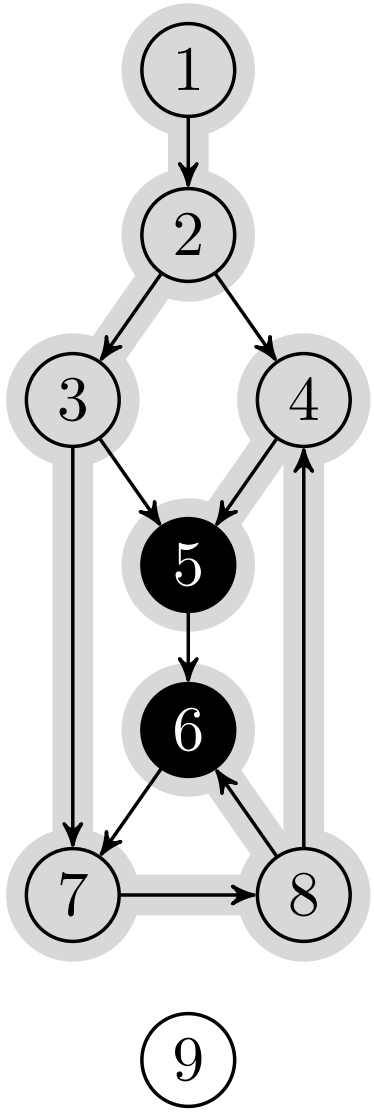
	5	4	5
	7	8	6
	8	3	7
t	4	7	8
	5	—	9



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	8	3	7
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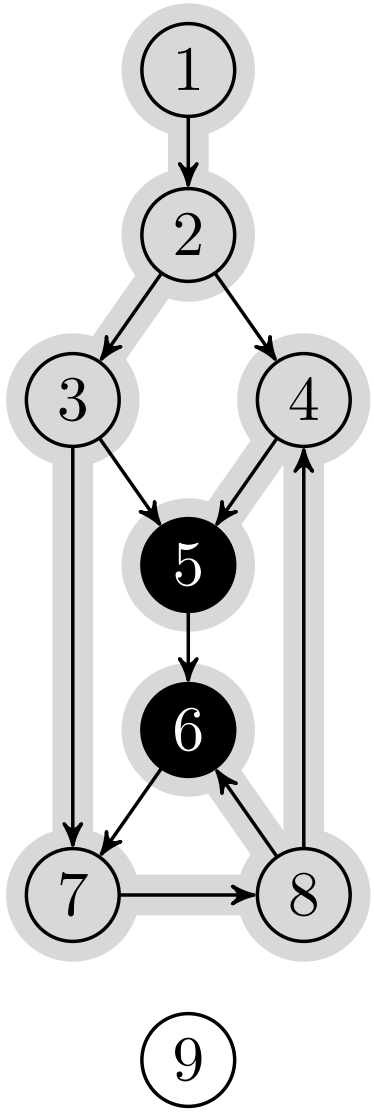

ITER-DFS-VISIT(G, s)

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15              if v.color == WHITE
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17                    PUSH(Q, v)
```
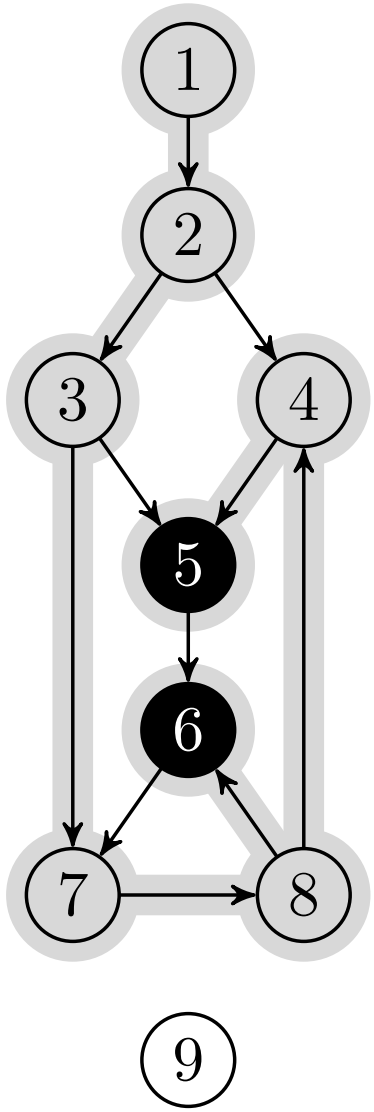

$u, v \;=\; 4, 6$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
t	4	7	8
	5	—	9



ITER-DFS-VISIT(G, s)

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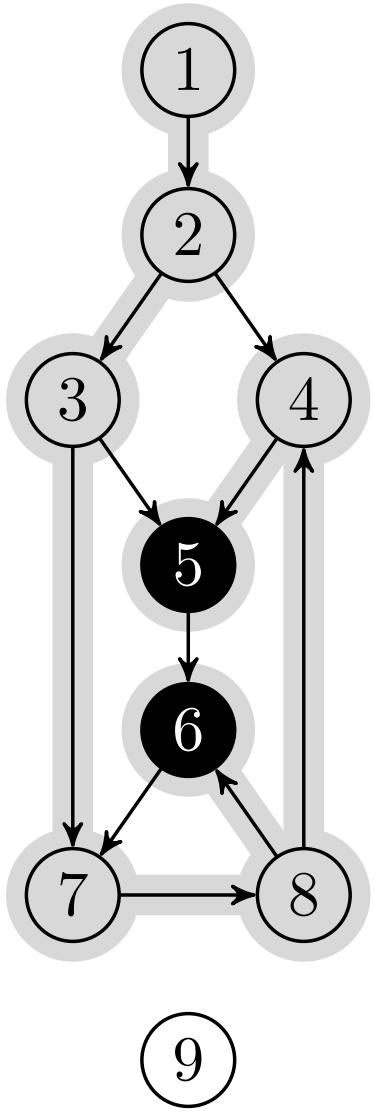
	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
t	4	7	8
	5	—	9



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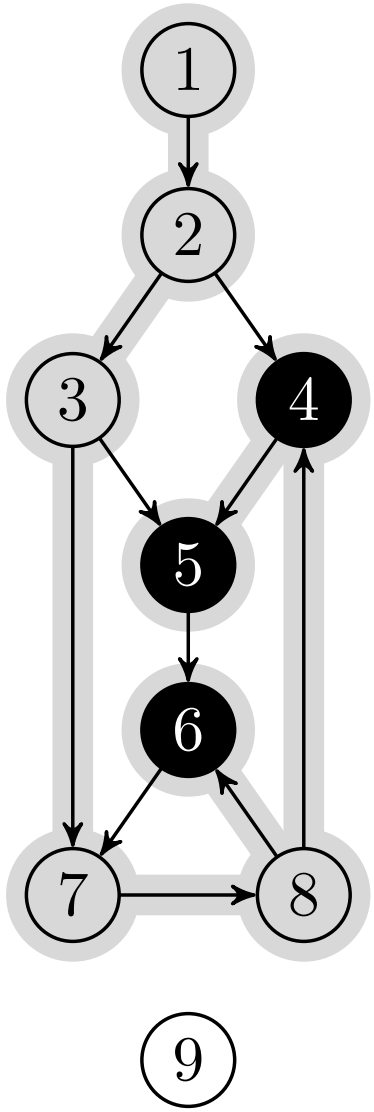
```

$u, v = 4, 6$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
t	4	7	8
	5	—	9



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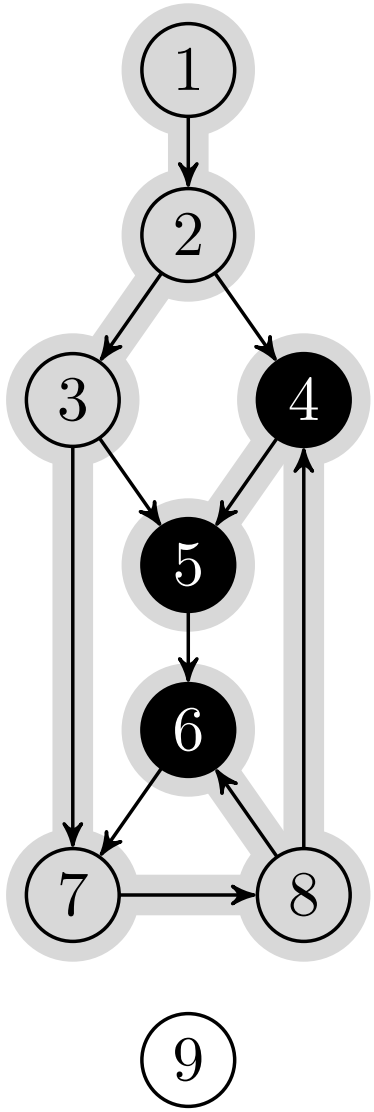
$u, v = 4, 6$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
t	8	3	7
	4	7	8
	5	—	9



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```
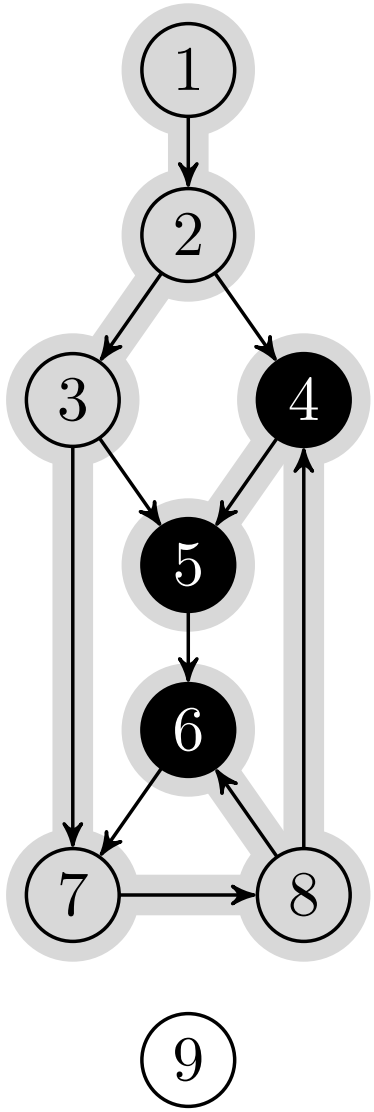

$u, v = 4, 6$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
t	8	3	7
	4	7	8
	5	—	9



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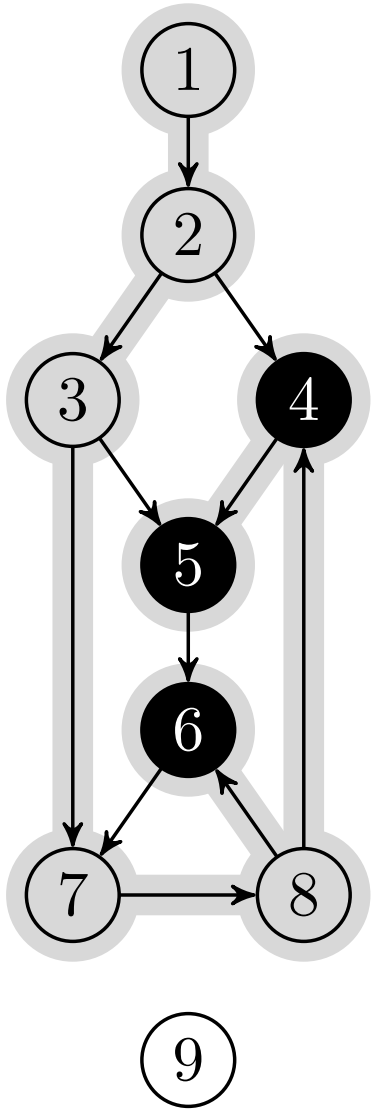
```

$u, v \;=\; 4, 6$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
t	8	3	7
	4	7	8
	5	—	9



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17                    PUSH(Q, v)
```
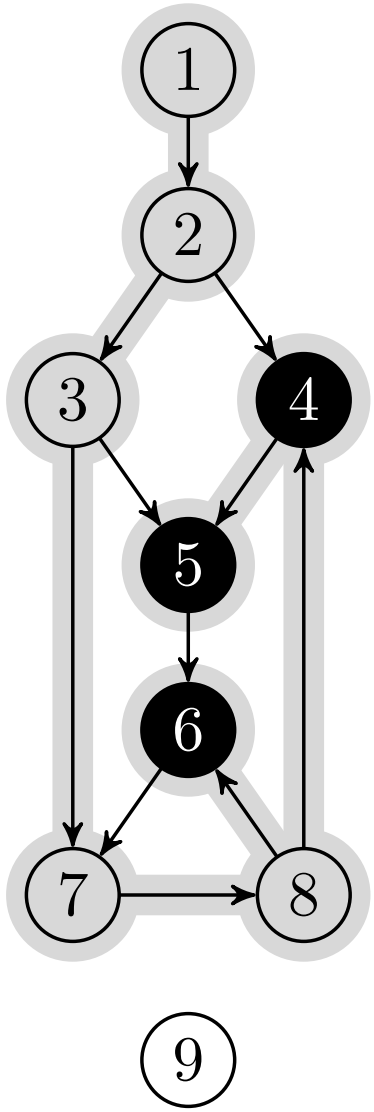

$u, v \;=\; 8, 6$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
t	8	3	7
	4	7	8
	5	—	9



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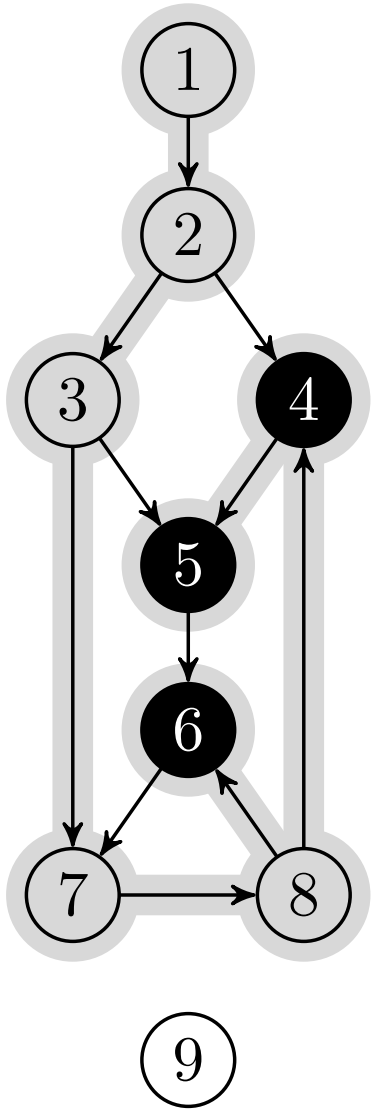
```

$u, v \;=\; 8, 6$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
	7	8	6
t	8	3	7
	4	7	8
	5	—	9



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$u, v \;=\; 8, 6$

	Q	π	
	1	—	1
	2	1	2
	4	2	3
	3	8	4
	5	4	5
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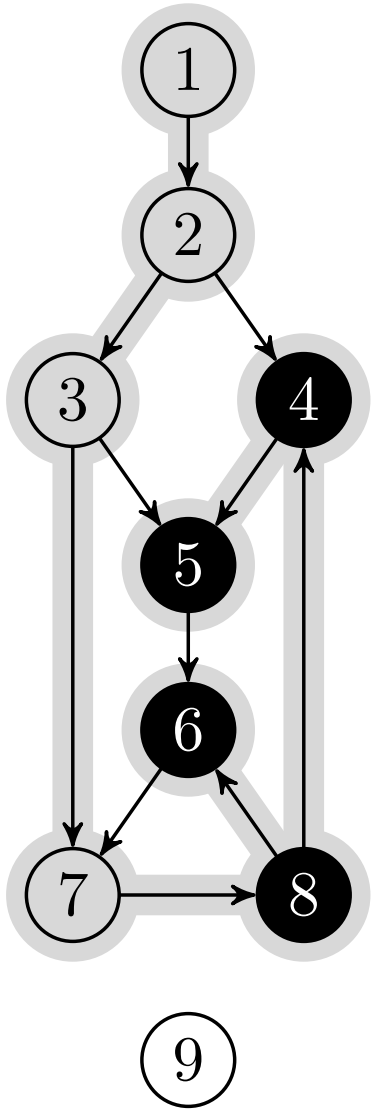

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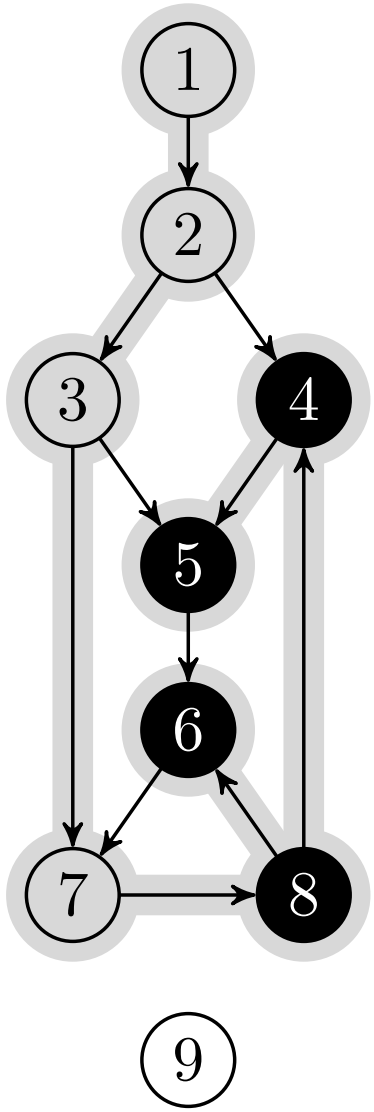

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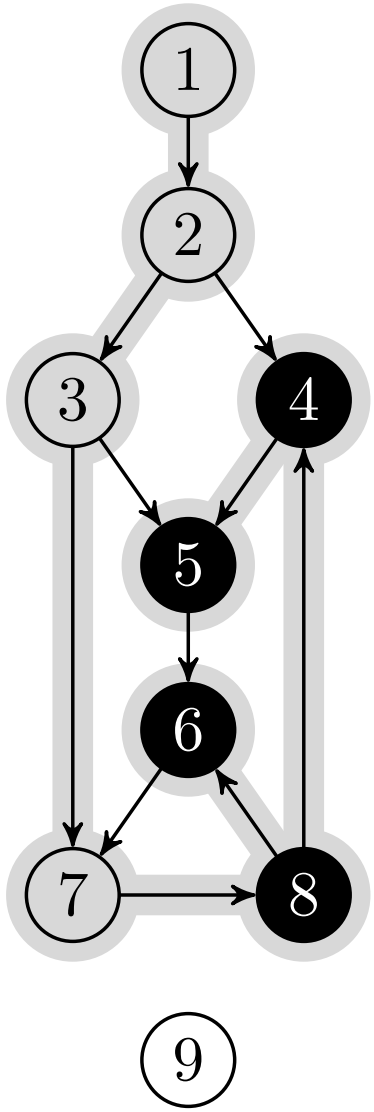

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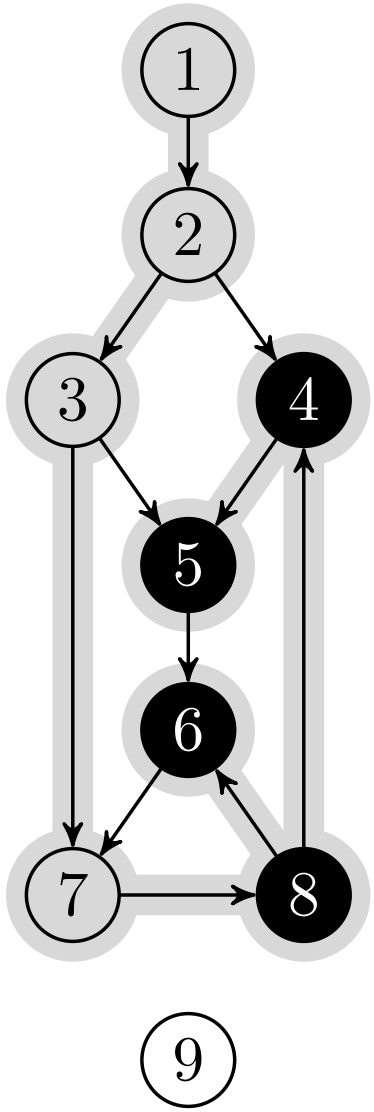

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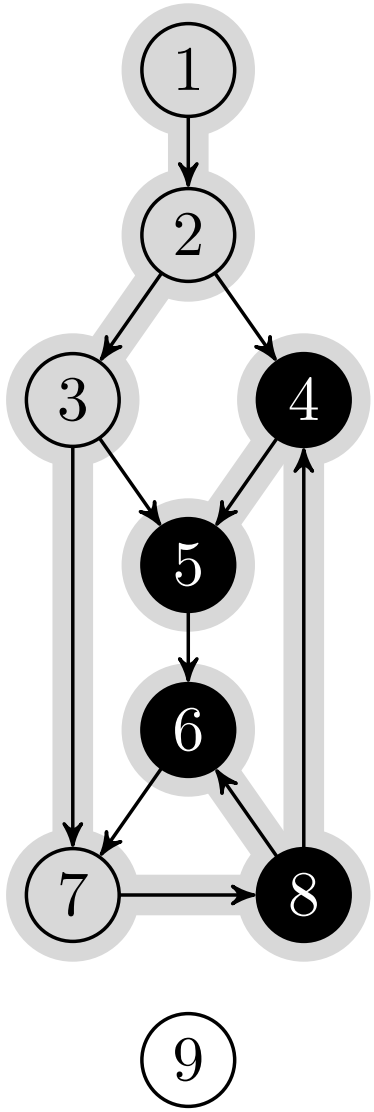

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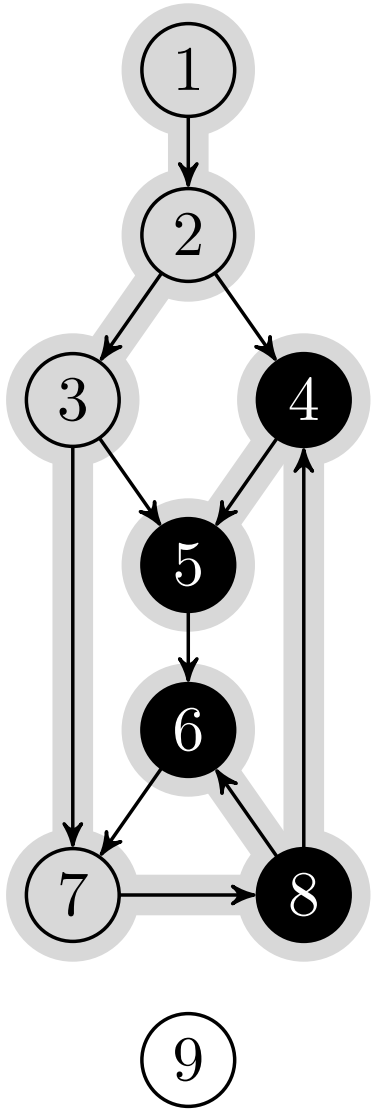

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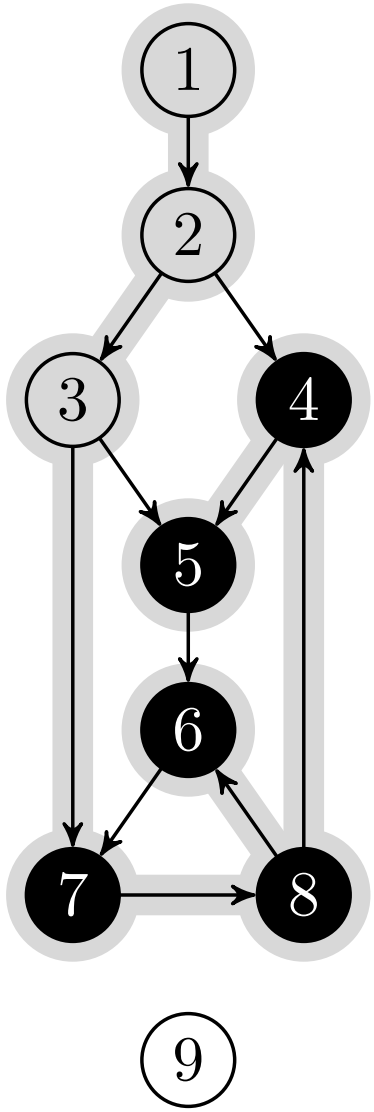

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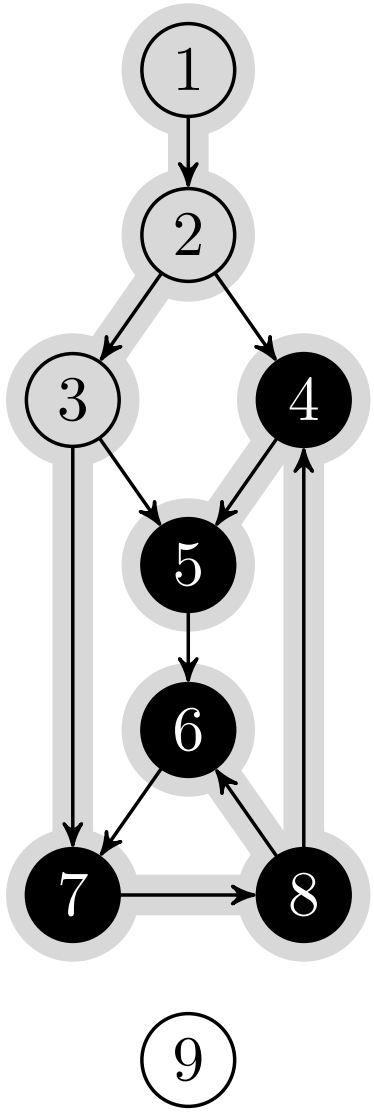

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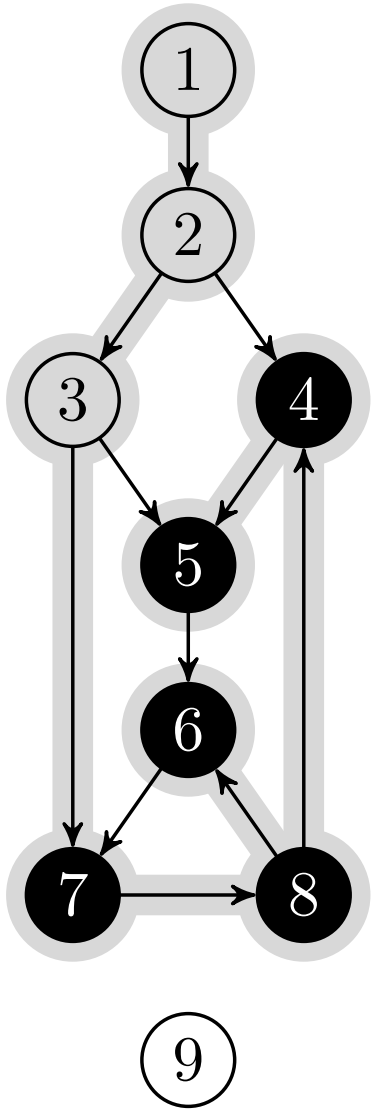

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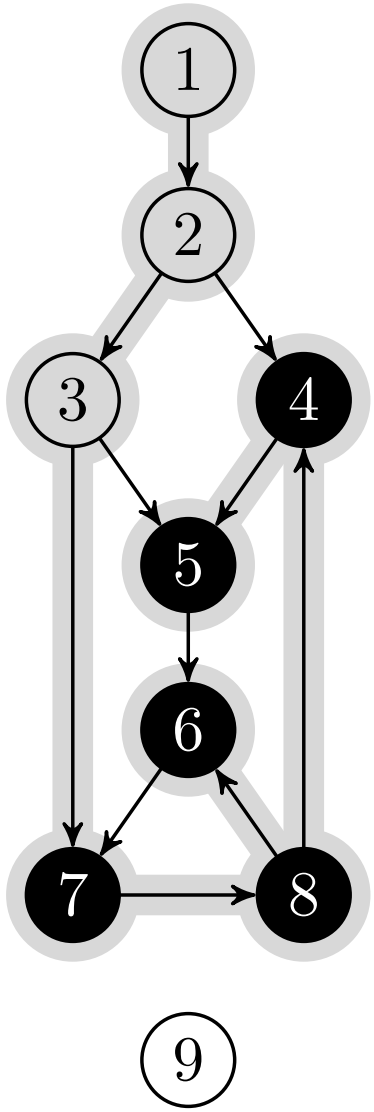

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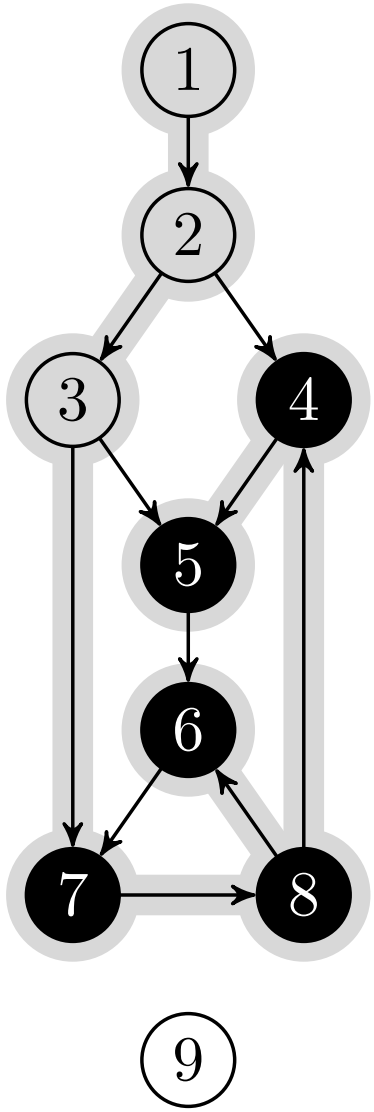

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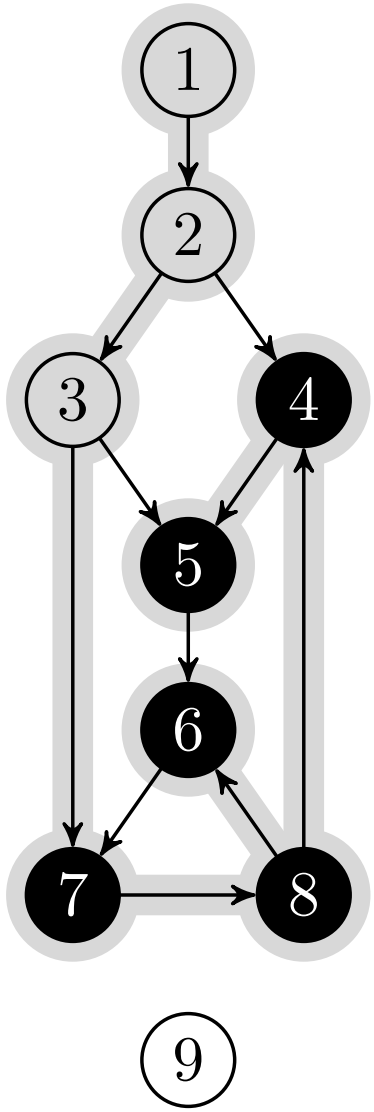

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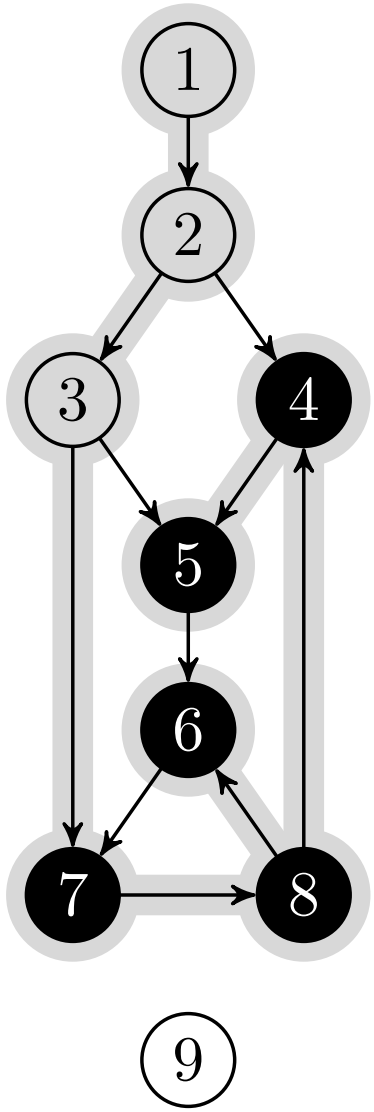

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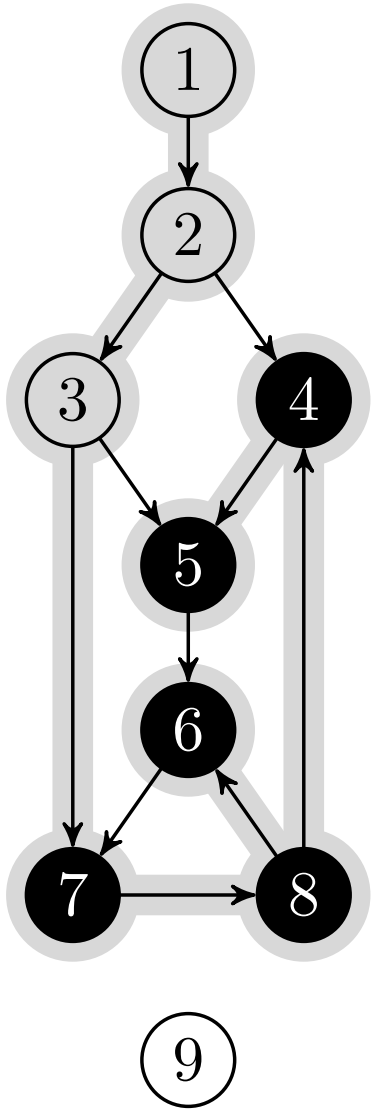

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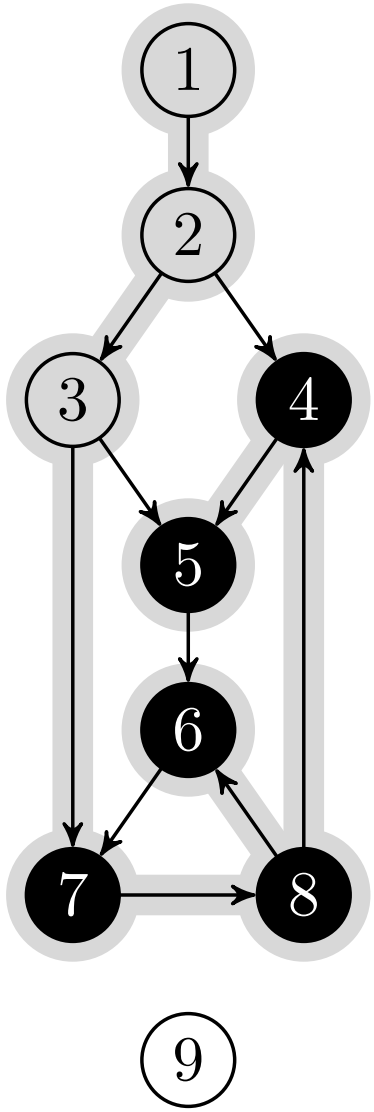

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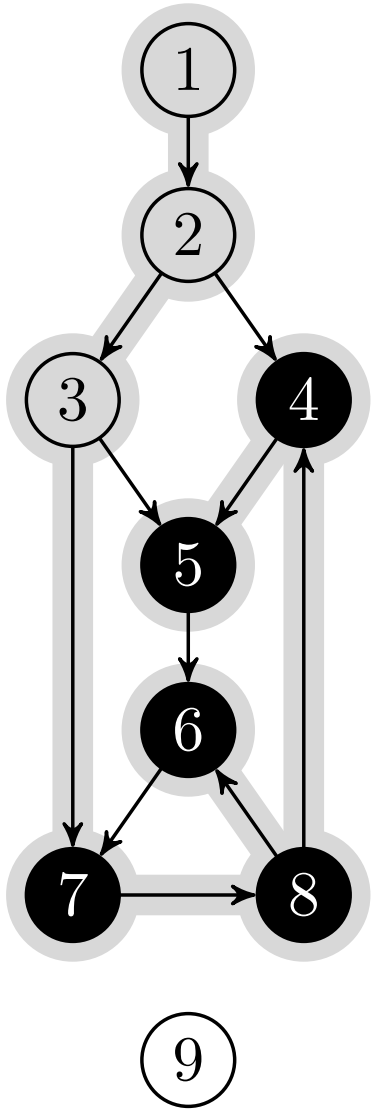

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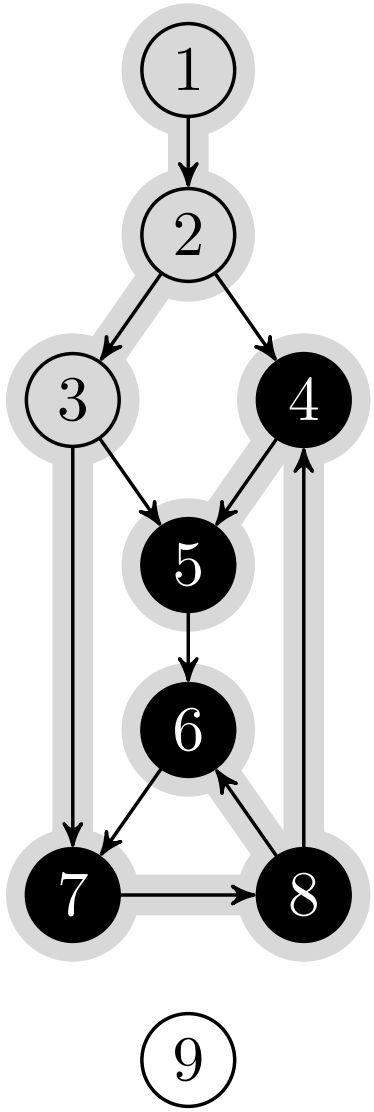

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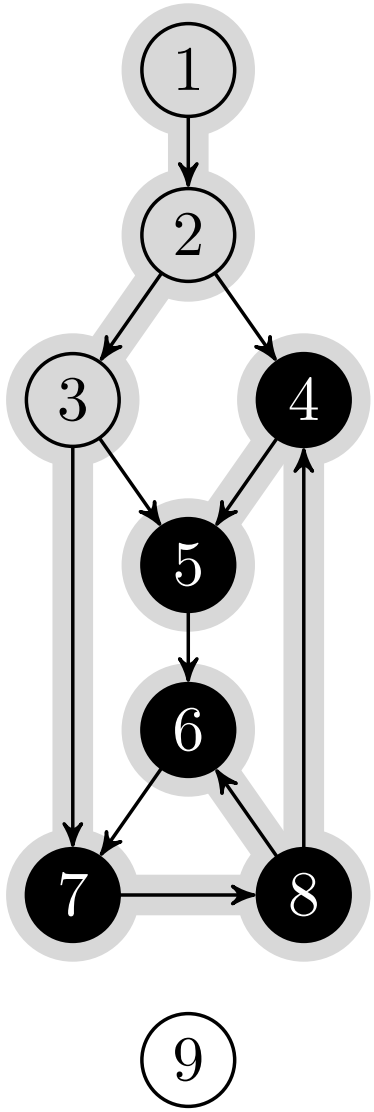

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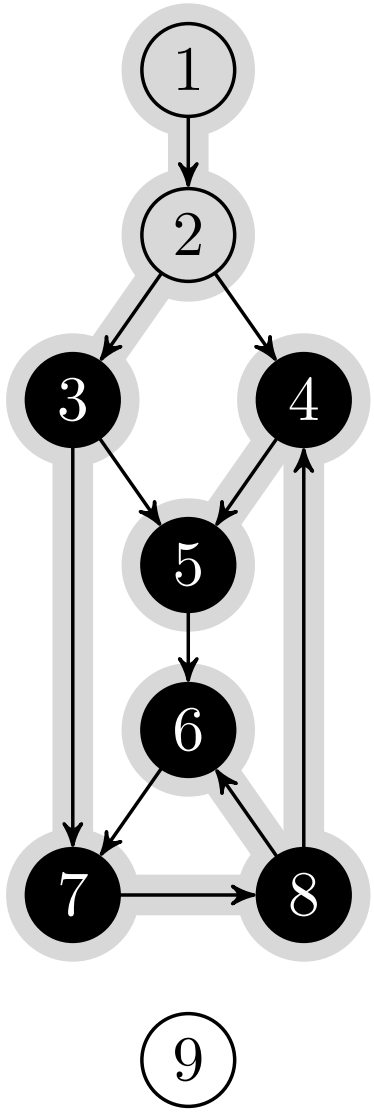

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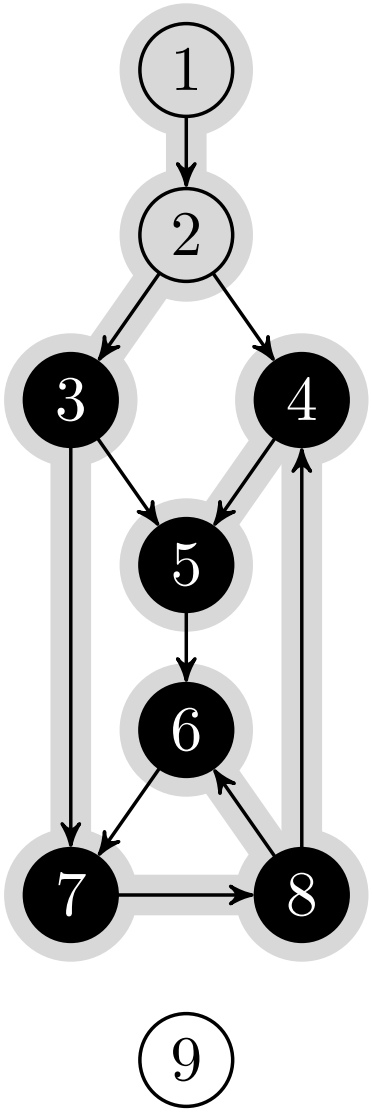

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```

$u, v = 3, 6$

	Q	π	
	1	—	1
	2	1	2
t	4	2	3
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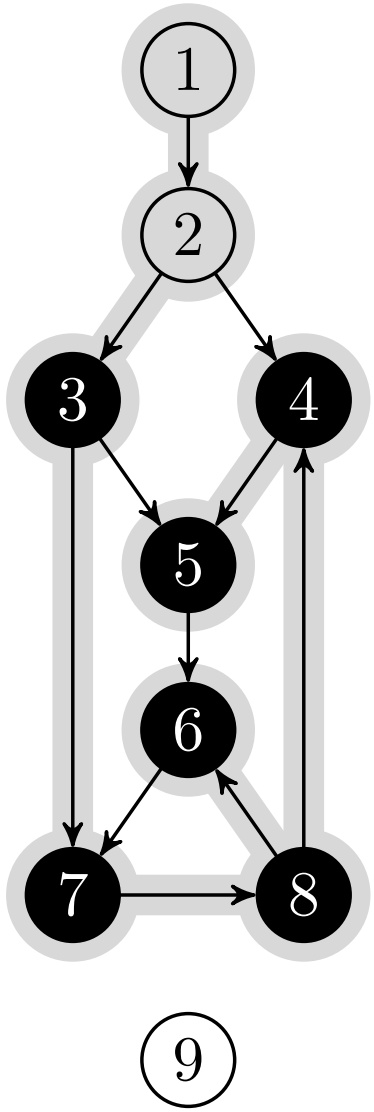

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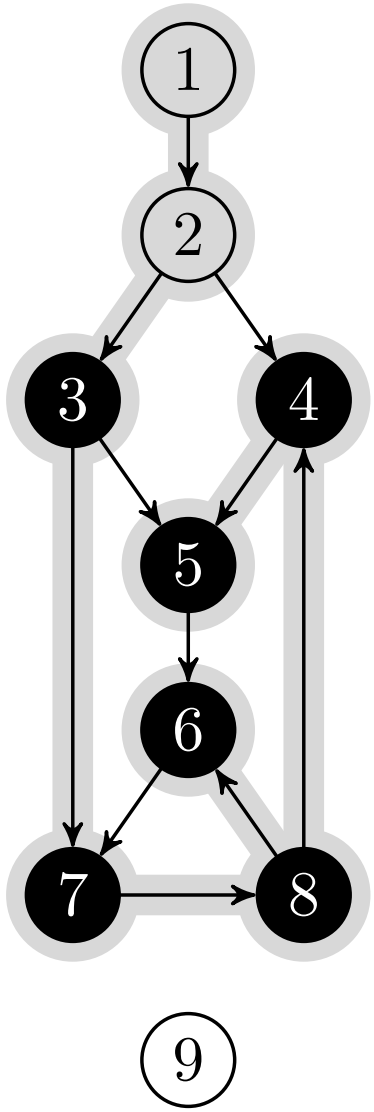

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$u, v = 4, 6$

	Q	π	
	1	—	1
	2	1	2
t	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
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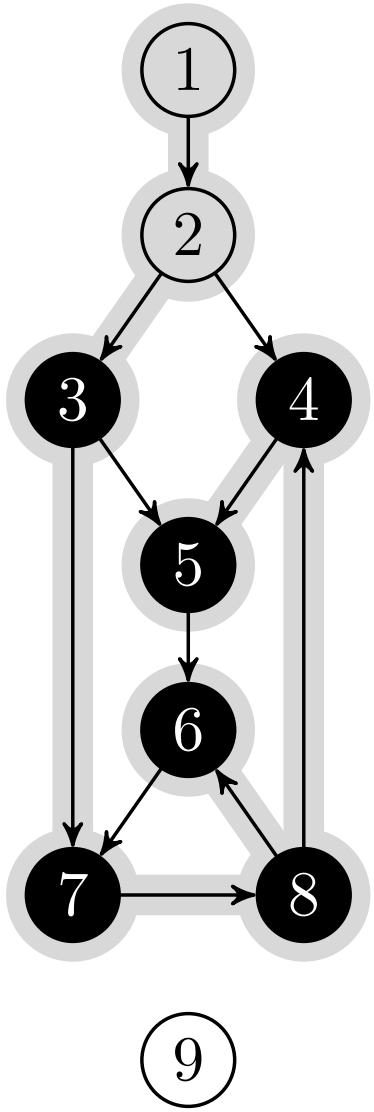

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$u, v \;=\; 4, 6$

	Q	π	
	1	—	1
	2	1	2
t	4	2	3
	3	8	4
	5	4	5
	7	8	6
	8	3	7
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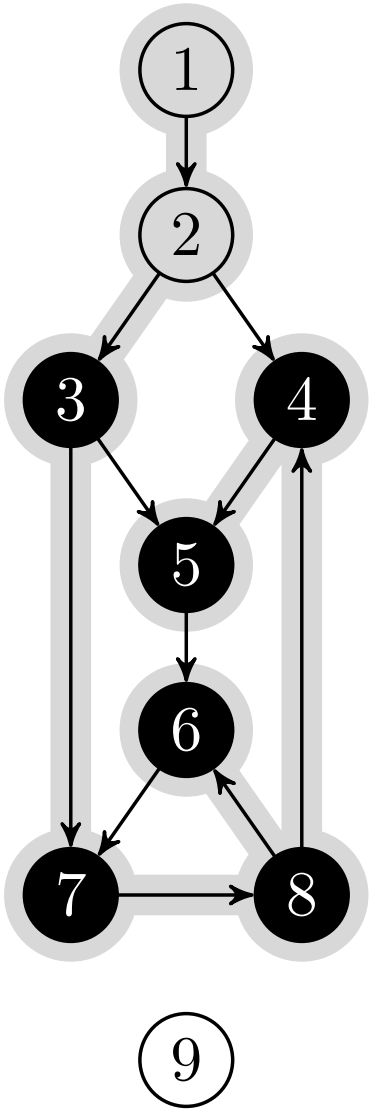

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$u, v \;=\; 4, 6$

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	2	1	2
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	8	3	7
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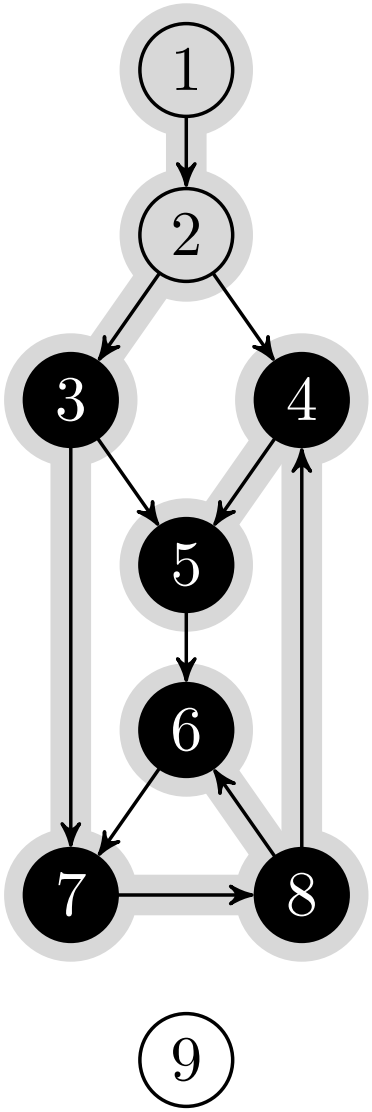

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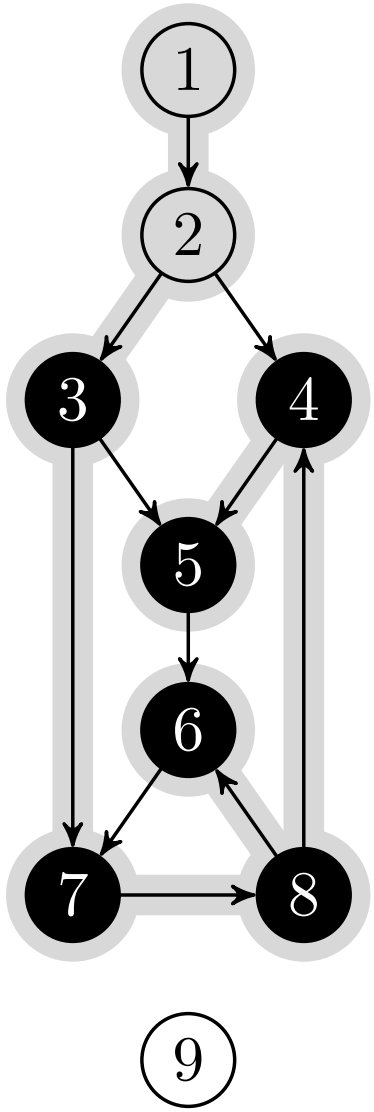

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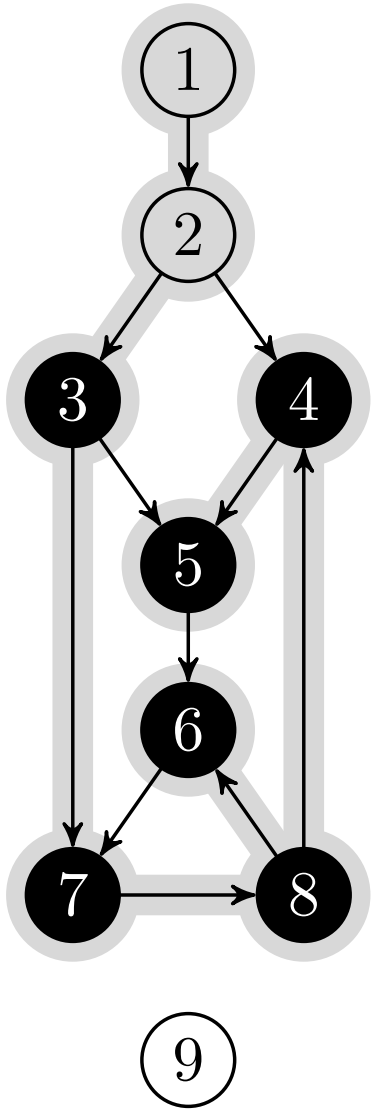

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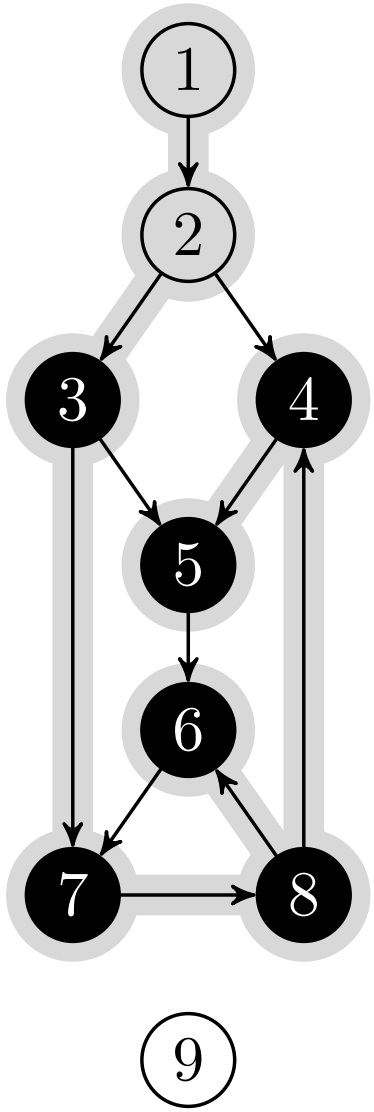

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	7	8	6
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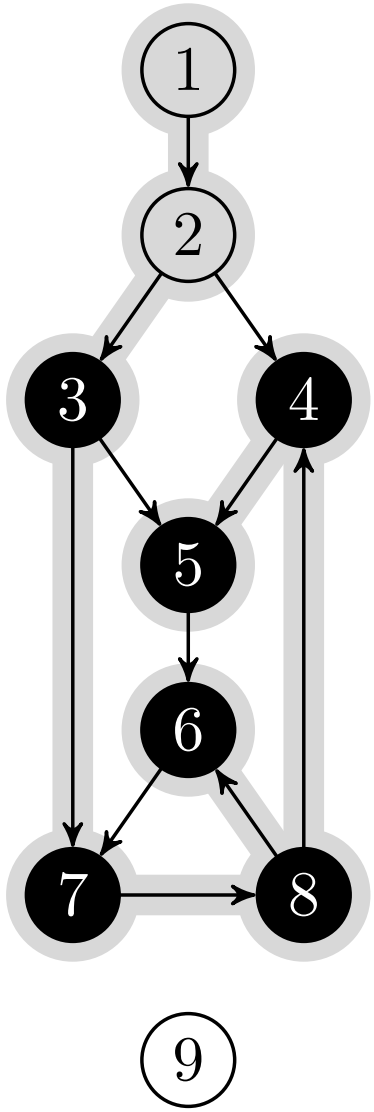

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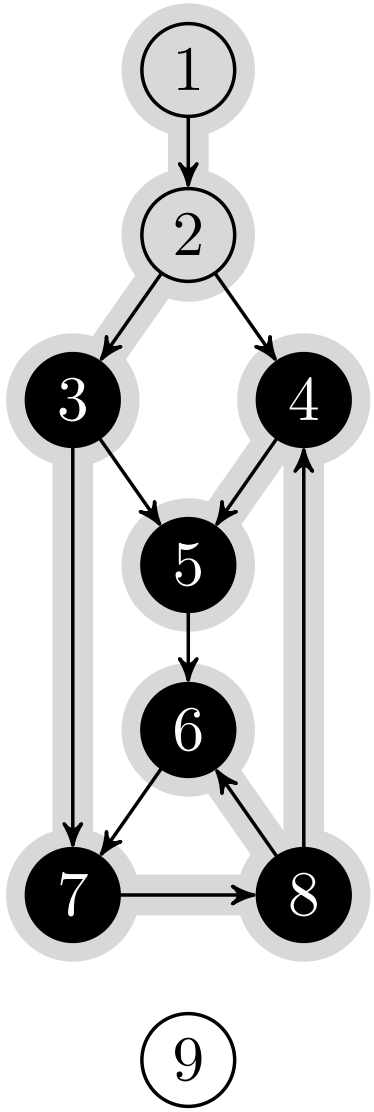

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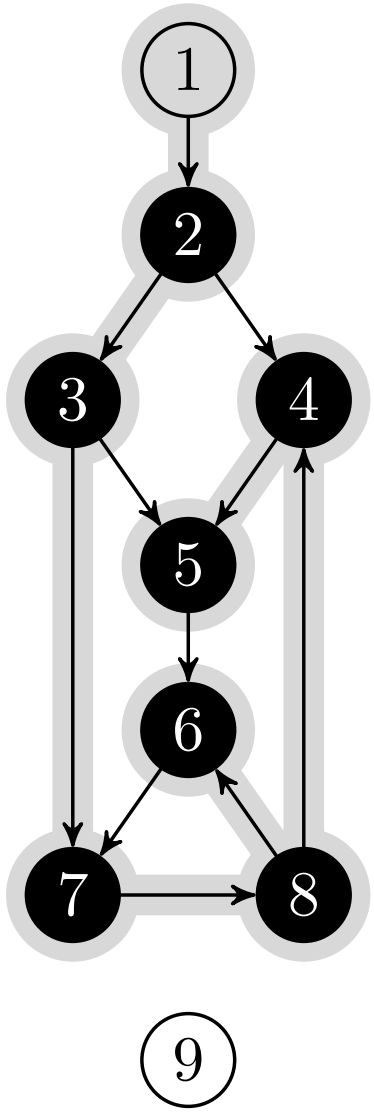

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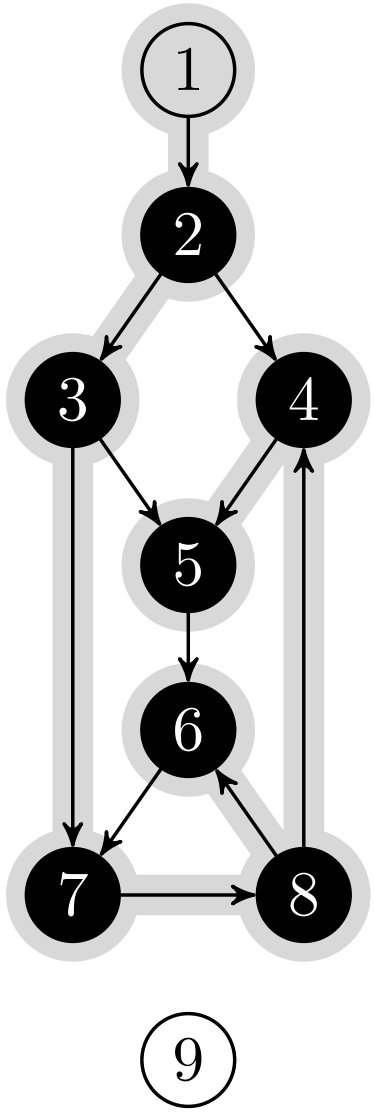

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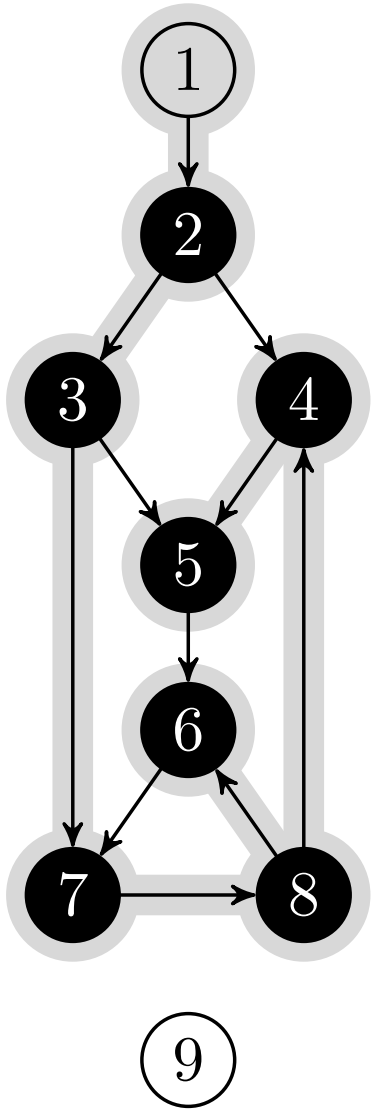

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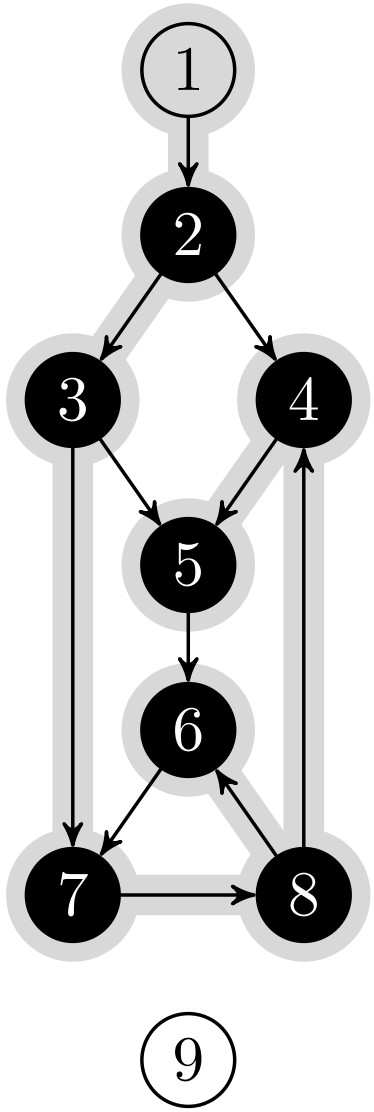

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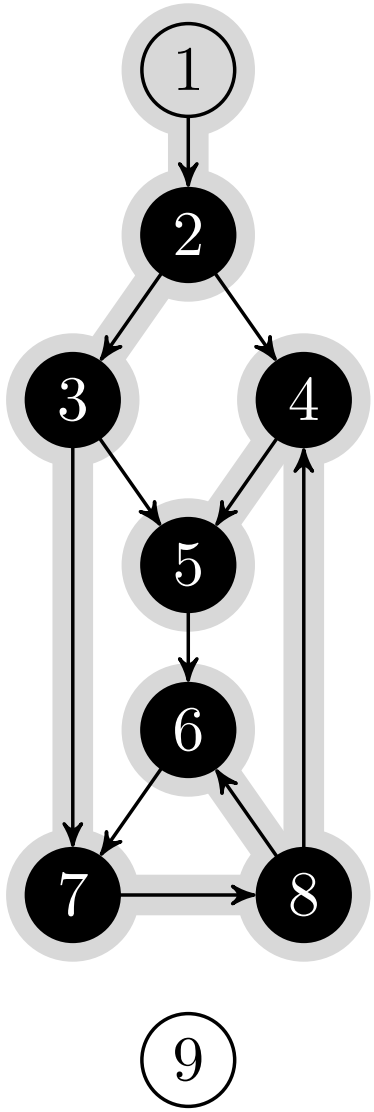

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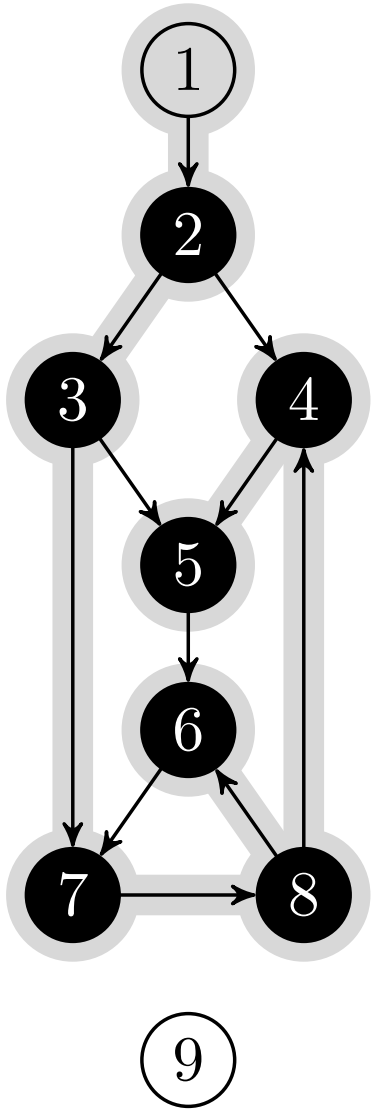

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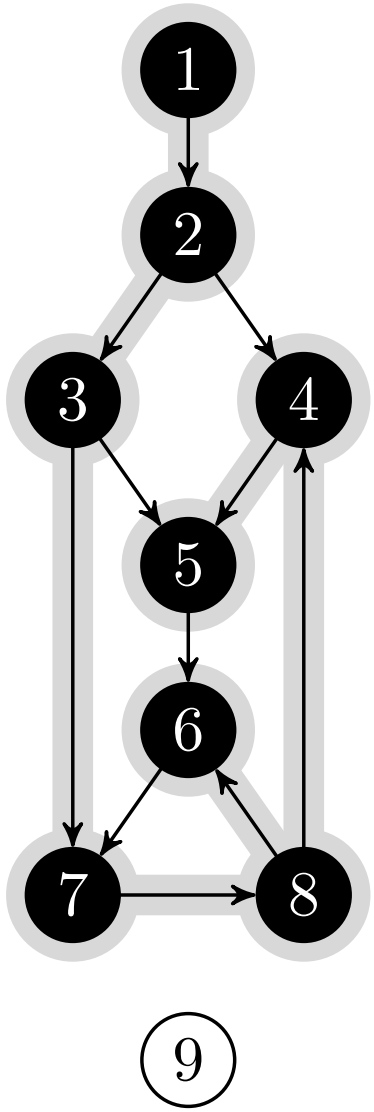

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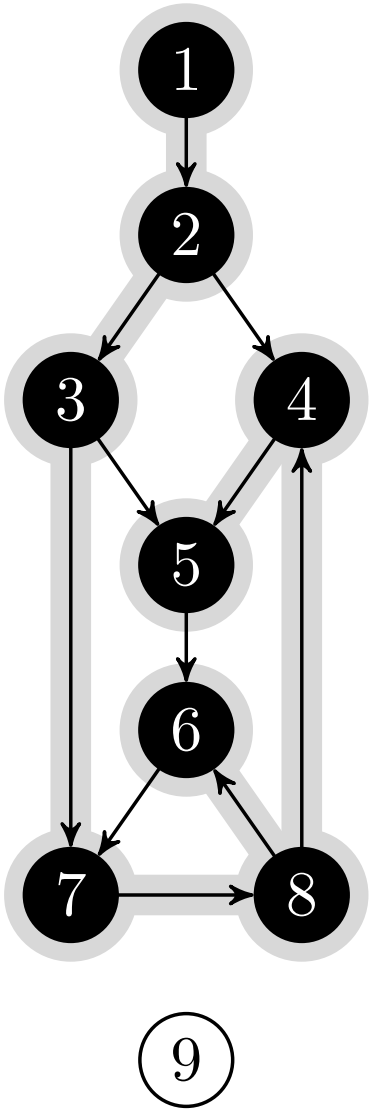

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