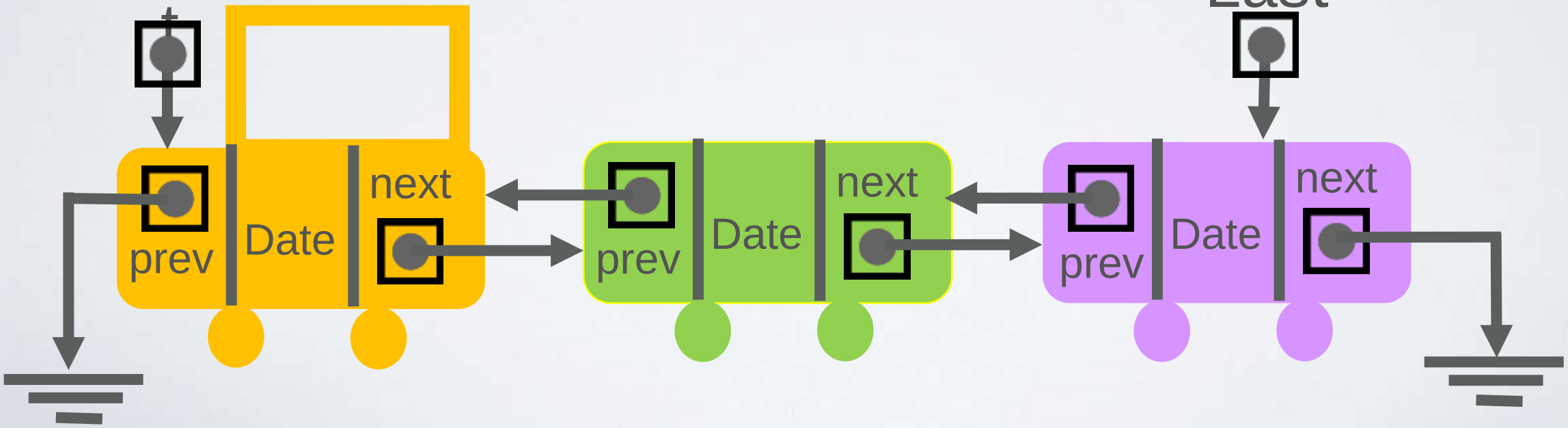
UNIVERSITATEA TEHNICĂ DIN CLUJ-NAPOCA

SDA CURS 2:

LISTA DUBLU INLANTUITA, LISTA SIMPLU INLANTUITA CIRCULARA, STIVA, COADA

LISTA DUBLU INLANTUITA

- Tip special de lista in care informatia de legatura a fiecarui element cuprinde atat adresa elementului *precedent* (`prev`) din lista cat si adresa elementului *urmator* (`next`) – inlantuire bidirectionala



LISTA DUBLU INLANTUITA – OPERATII

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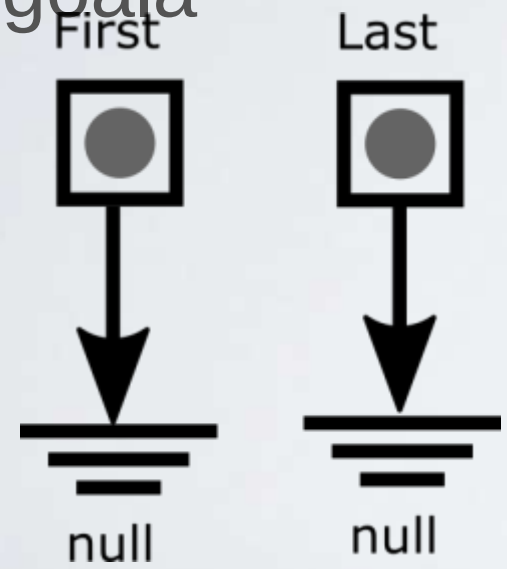
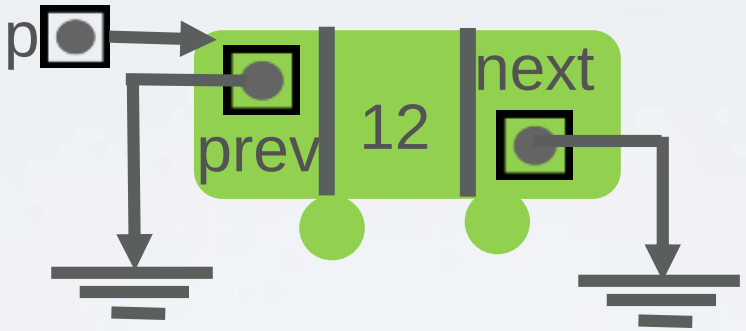
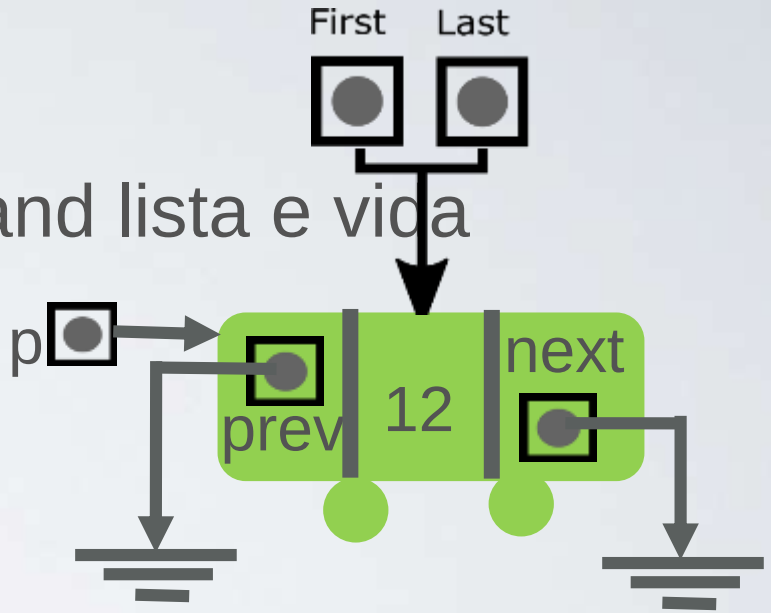
create_empty:
creaza o lista goala



insert_first - *cream elementul*



cand lista e vida




```
NodeDL *p = (NodeDL *)malloc(sizeof(NodeDL));
p->key  = 12;
p->next = NULL;
p->prev = NULL;
```

```
if (first == NULL)
{
    first = last = p;
}
```

```
NodeDL *first = NULL, *last = NULL;
```

LISTA DUBLU INLANTUITA – INSERT_FIRST

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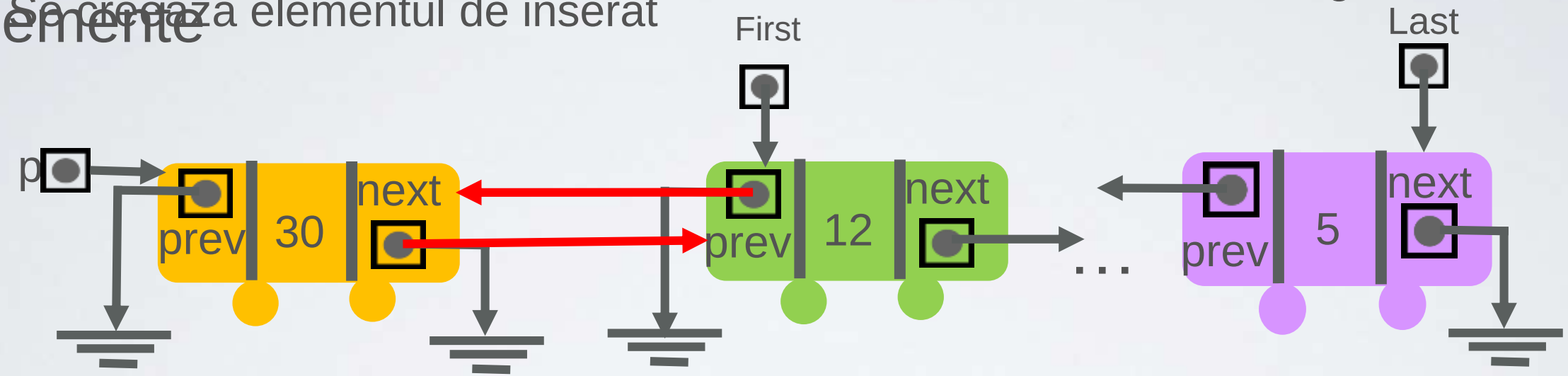
insertFirst – cand lista are elemente

- Se creeaza elementul de inserat

Se actualizeaza legaturile din lista.




```
NodeDL *p = (NodeDL *)malloc(sizeof(NodeDL));
p->key  = 30;
p->next = NULL;
p->prev = NULL;
```

```
if (first != NULL)
{    /* list is not empty */
     p->next      = first;
     first->prev = p;
     first        = p;
}
```

LISTA DUBLU INLANTUITA INSERT_LAST

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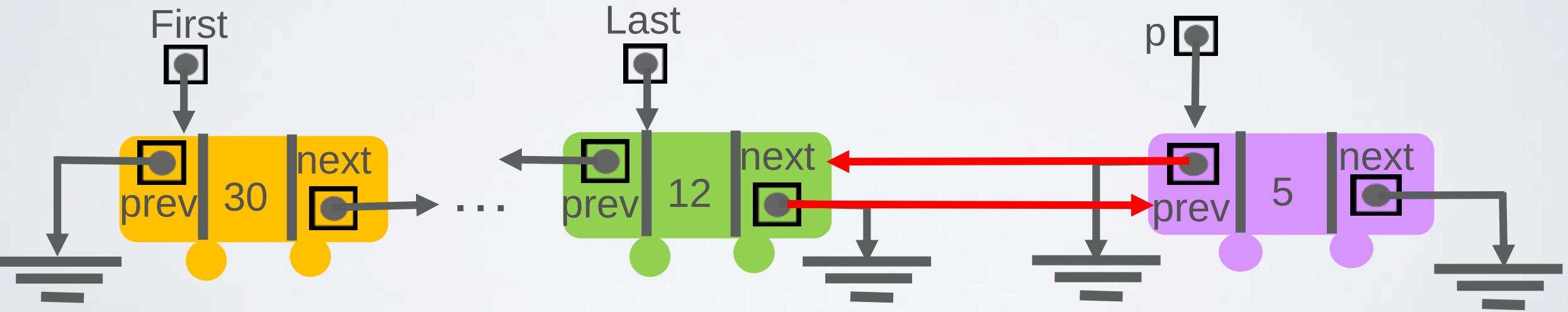
2. Inserare la final (append):
   - Lista goala - ca si la insertFirst
   - Lista nu e goala



LISTA DUBLU INLANTUITA
INSERT IN INTERIORUL LISTEI

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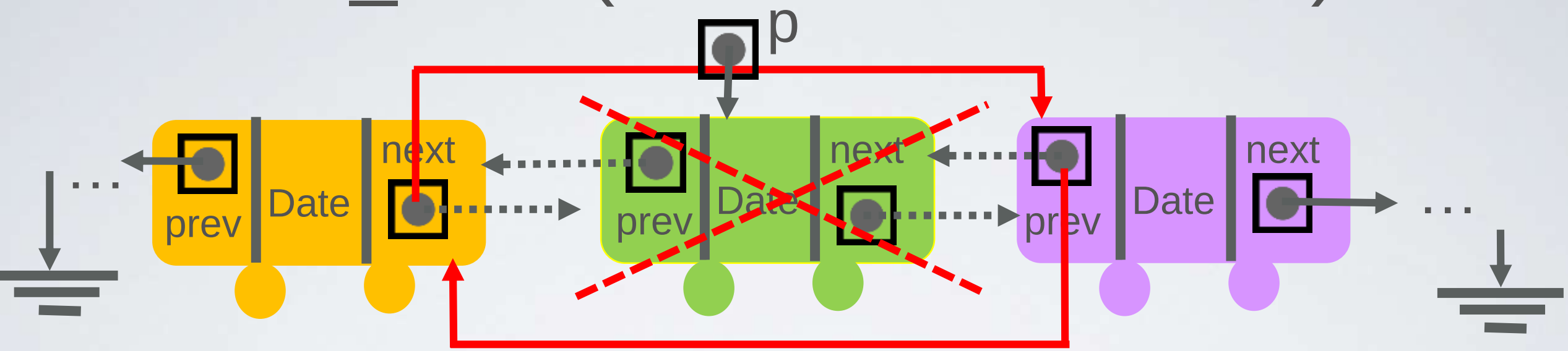
3. Inserare in lista ordonata, la pozitia k, inainte/dupa o anumita cheie – cazuri posibile:

- Lista goala: ca si mai inainte
- Lista cu elemente:
  - Inainte de primul nod (i.e. inserare la inceput)
  - Dupa ultimul nod (i.e. append)
  - In interiorul listei
    - trebuie traversata lista, si stabilit un pointer (*de ce nu 2?*):
      - nodul curent (va deveni `next` pt nodul inserat)
      - nodul inserat va deveni `prev` pentru nodul curent
- Exercitiu!!!!

LISTA DUBLU INLANTUITA DELETE_KEY (CAZUL GENERAL)

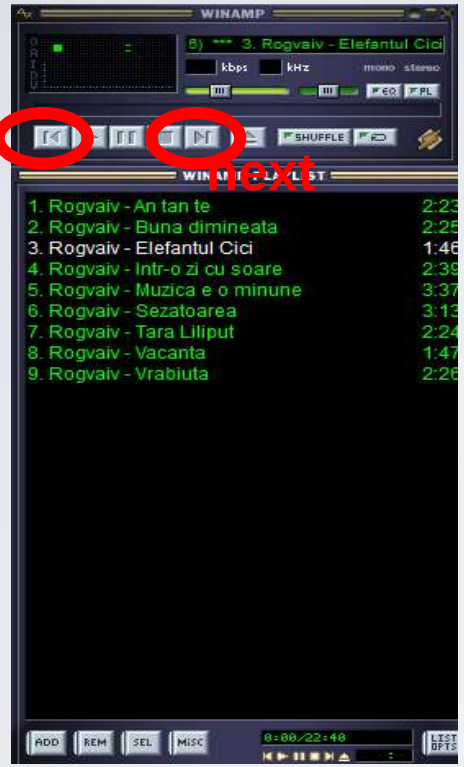


Cazuri speciale?

Pseudocod:

```
LIST-DELETE(L,p)
  if p.prev != NIL
        p.prev.next = p.next
  else L.first = p.next
  if p.next != NIL
        p.next.prev = p.prev
  else L.last = p.prev
```

LISTA DUBLU INLANTUITA – UTILITATE



- Player de muzica cu butoane de next si previous
- Cache-ul din browsere, cu functionalitatea de *BACK-FORWARD* pe pagini
- Functionalitatea de *UNDO-REDO*
- Sisteme de operare – *planner* de fire de

LISTA SIMPLU VS DUBLU INLANTUITA EFICIENTA

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Operatie	Lista simplu inlantuita, cu first si last	Lista dublu inlantuita, cu first si last
Inserare la inceput	O(1)	O(1)
Inserare la sfarsit	O(1)	O(1)
Inserare in interiorul listei (adresa cunoscuta)	O(n)	O(1)
Cautare dupa cheie	O(n)	O(n)
Stergere de la inceput	O(1)	O(1)
Stergere de la sfarsit	O(n)	O(1)
Stergere din interior (adresa nod data)	O(n)	O(1)

LISTA CIRCULARA

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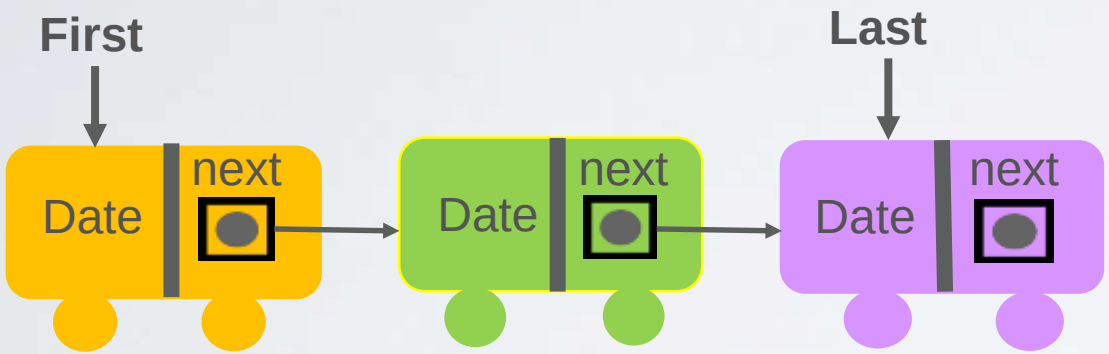
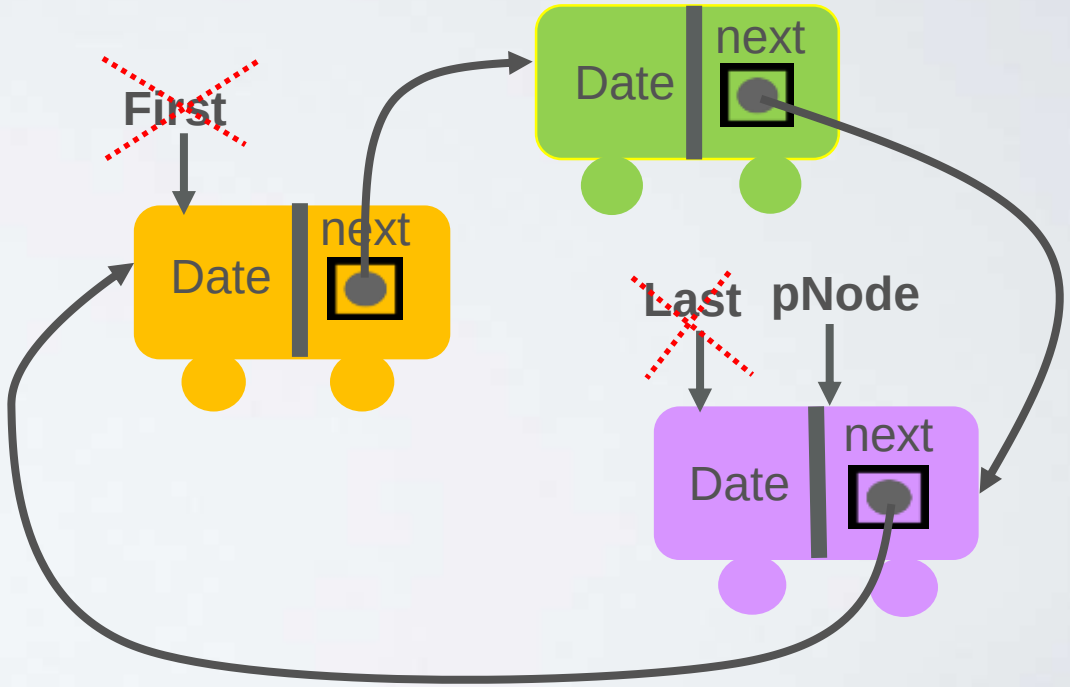
Lista simplu/dublu inlantuita cu proprietatea ca primul element din lista urmeaza dupa ultimul element (pointerul next al ultimului element pointeaza catre primul element).



Lista simplu inlantuita



Lista simplu inlantuita circulara

LISTA CIRCULARA

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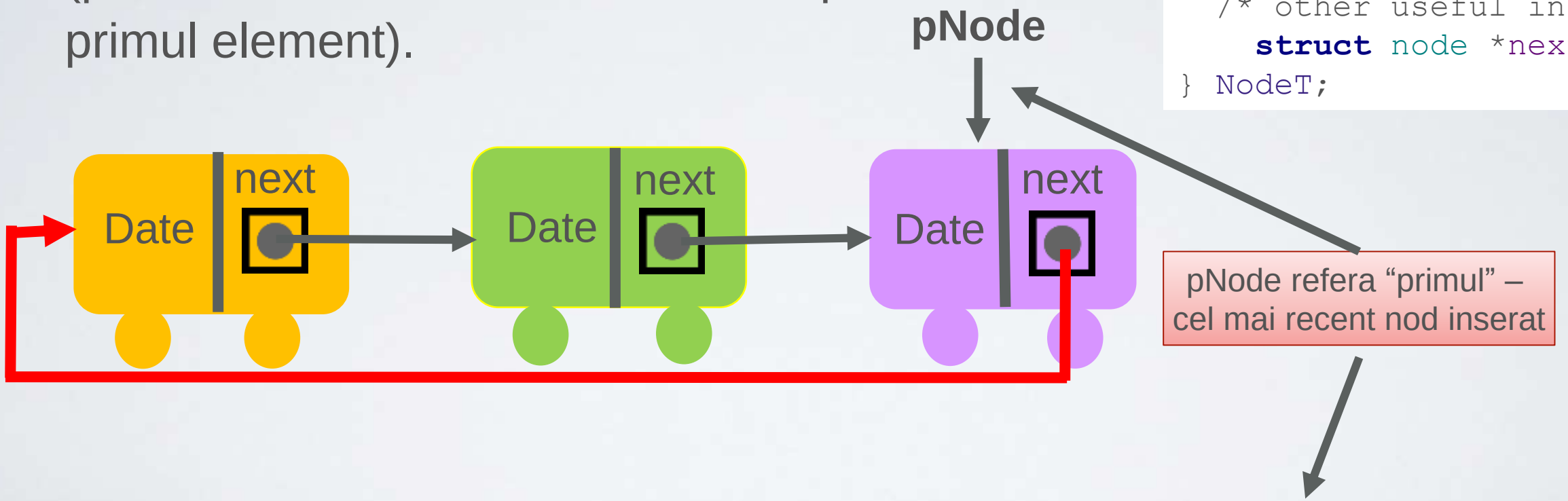
- Lista simplu/dublu inlantuita cu proprietatea ca primul element din lista urmeaza dupa ultimul element (pointerul next al ultimului element pointeaza catre primul element).

```
typedef struct node {
    int key;
  /* other useful info */
    struct node *next;
} NodeT;
```



Se foloseste un singur pointer ***pNode*** *pentru a indica un element din lista – e.g.* ***cel mai recent nod inserat***

LISTA CIRCULARA - OPERATII

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- Cautarea unui element (dupa cheie)
- Inserarea unui element
  - Pe **prima**/ultima pozitie in raport cu cel mai recent nod inserat (**inainte** / dupa pNode)
  - Dupa un anumit element
  - …
- Stergerea unui element
  - Primul/ultimul (inainte / dupa pNode)
  - Dupa cheie
- **Exercitii !**

LISTA SIMPLU INLANTUITA CIRCULARA - OPERATII

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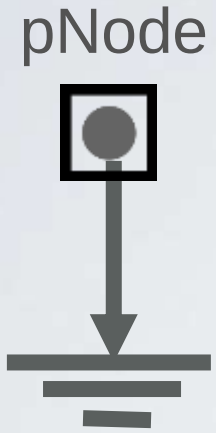
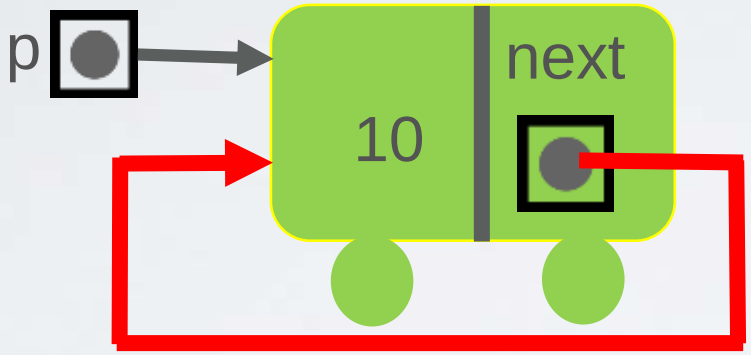
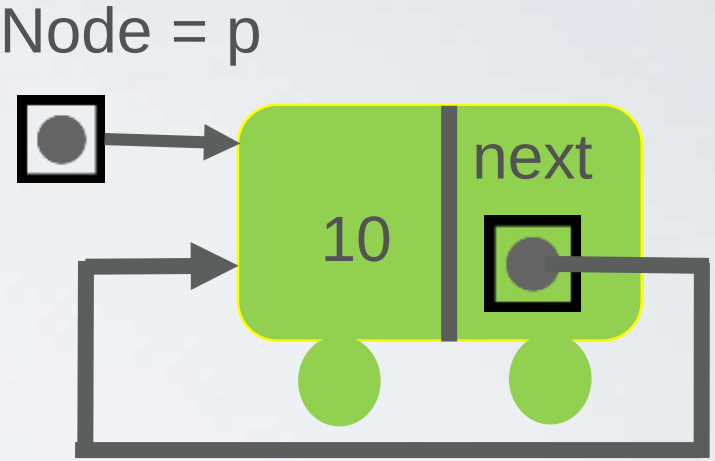
insert_first:




```
NodeT *pNode = NULL;
```




```
NodeT *p = (NodeT *) malloc(sizeof(NodeT));
p->key = 10;
p->next = p;
```




```
if (pNode == NULL)
{    /* empty list */
     pNode = p;
}
else
{    /* list is not empty */
     p->next = pNode->next;
     pNode->next = p;
     pNode = p; /* pNode points to most recently
added element*/
}
```

LISTA CIRCULARA - UTILITATE

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- Utila pentru implementarea unei cozi
  - Mentinem pointer catre ultimul nod inserat (*tail*); *head* va fi nodul care urmeaza dupa *tail*
- Liste circulare dublu inlantuite se utilizeaza in implementarea unor structuri complexe (e.g. Fibonacci Heaps)

LISTA SIMPLU INLANTUITA CIRCULARA - APLICATII

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- Problema lui Josephus*:
  - **n** copii sunt asezati in cerc. Incep sa numere de la primul copil, si fiecare al **m**-lea copil iese din cerc. Castiga jocul ultimul copil ramas in cerc.
  - E.g. Josephus(8,3) = {3,6,1,5,2,8,4,**7**}

LISTE INLANTUITE CU SANTINELA

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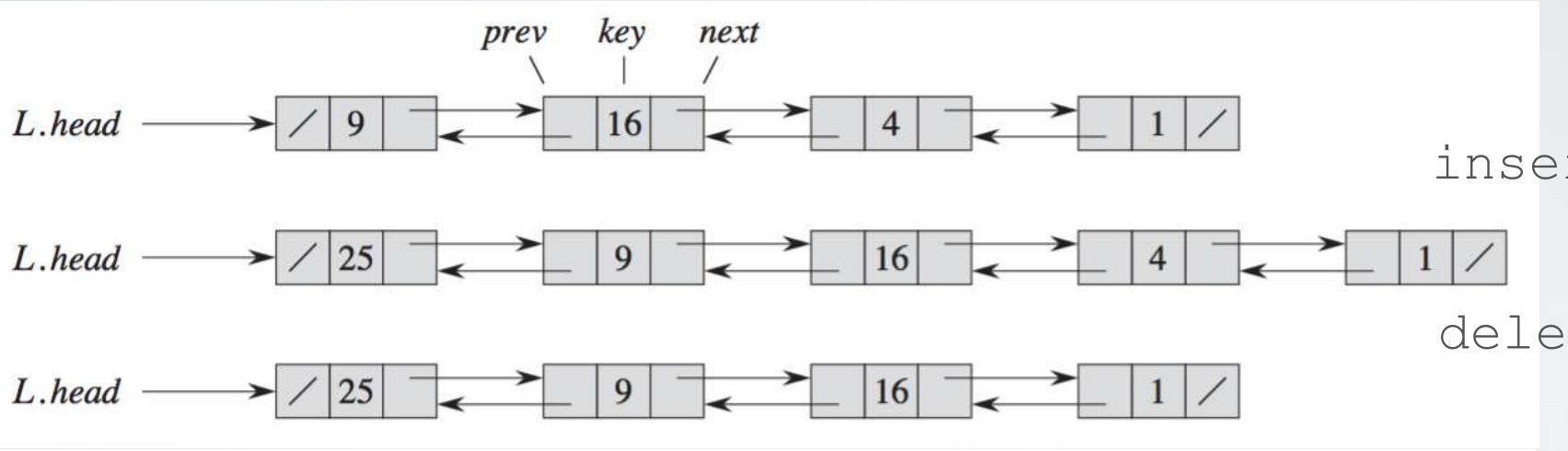
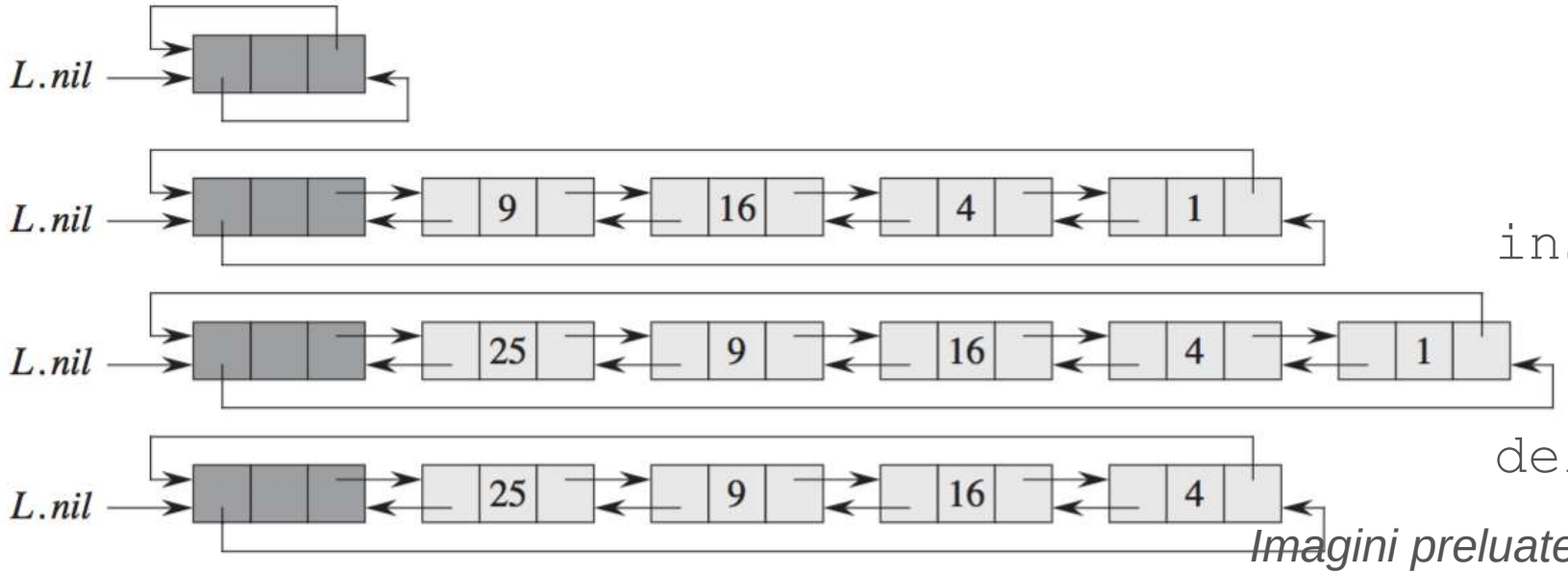
- O santinela este un element de lista *dummy* care ne permite sa eliminam necesitatea de a trata cazurile speciale (NULL).
  - nu contine informatie
  - contine toate campurile celorlalte elemente de lista (i.e. legaturile `prev` si `next`)
  - oricand avem in cod o referinta catre NULL, se inlocuieste cu referinta catre santinela.
  - lista dublu inlantuita -> lista dublu inlantuita circulara (daca utilizam santinela)

LISTA DUBLU INLANTUITA - FARA/CU SANTINELA




```
insert_first(L, 25)
```

```
delete_key(L, 4)
```

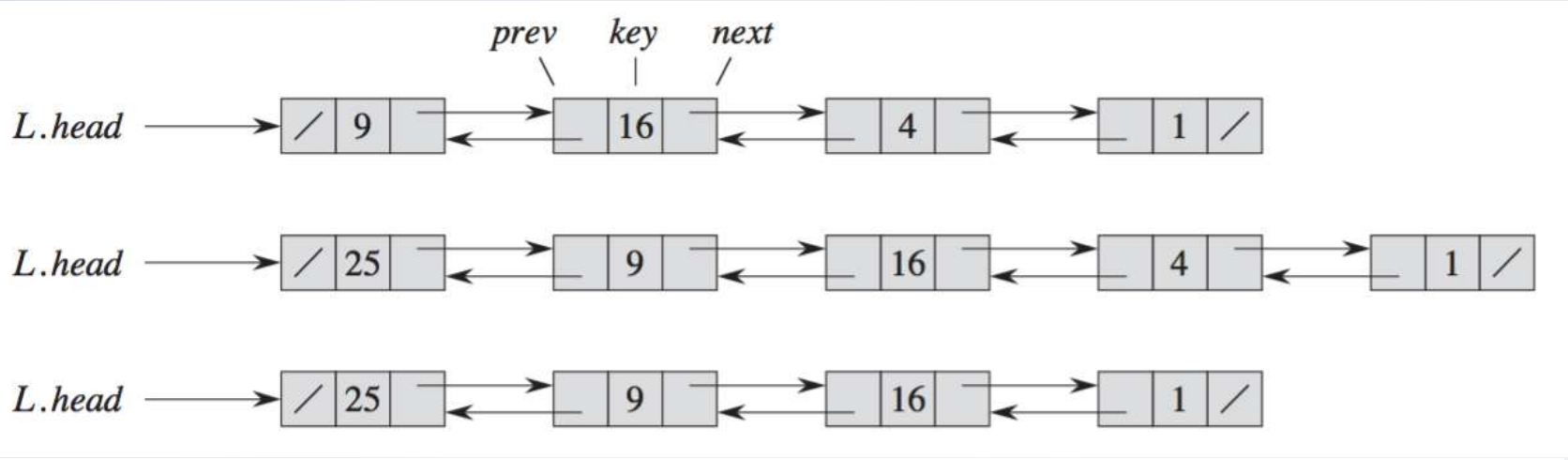


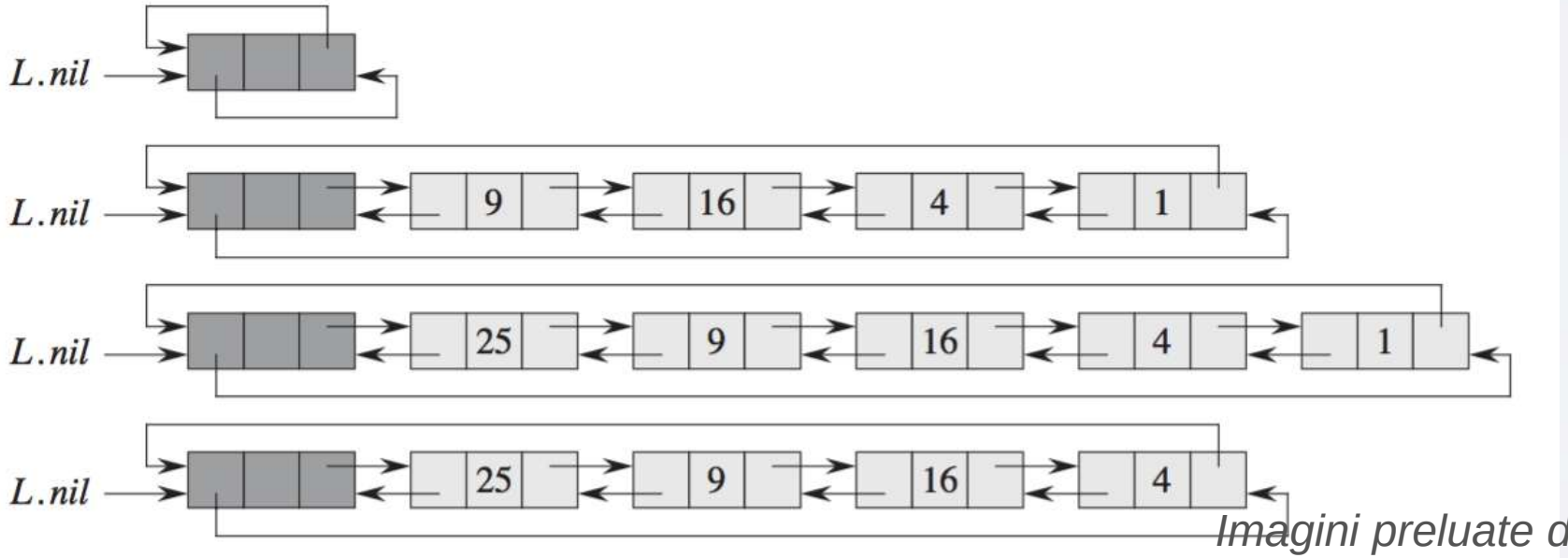

```
insert_first(L, 25)
```

```
delete_key(L, 1)
```

Imagini preluate din Th. Cormen – "Introduction to algorithm

LISTA DUBLU INLANTUITA - FARA/CU SANTINELA






```
delete_key(L,p)
   if p.prev != NIL
         p.prev.next = p.next
   else L.head = p.next
   if p.next != NIL
         p.next.prev = p.prev
```

```
delete_key_s(L,p)
   p.prev.next = p.next
   p.next.prev = p.prev
```

Imagini preluate din Th. Cormen – "Introduction to algorithm

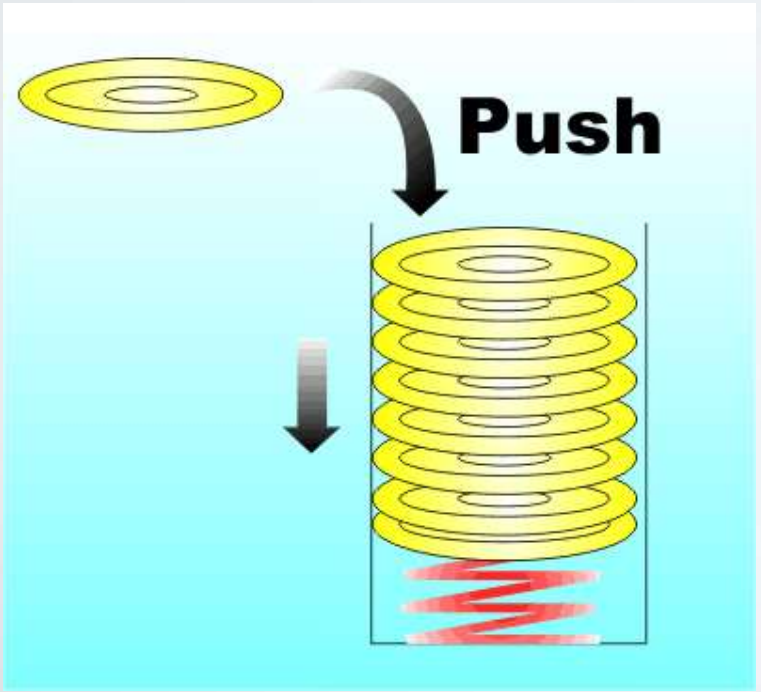
STIVA

- o colectie de elemente cu politica de acces (inserare/stergere) de tip *LIFO* (*Last-In-First-Out*)
- elementele sunt inserate astfel incat, la orice moment, doar cel mai recent element inserat poate fi eliminat

STIVA
OPERATII FUNDAMENTALE

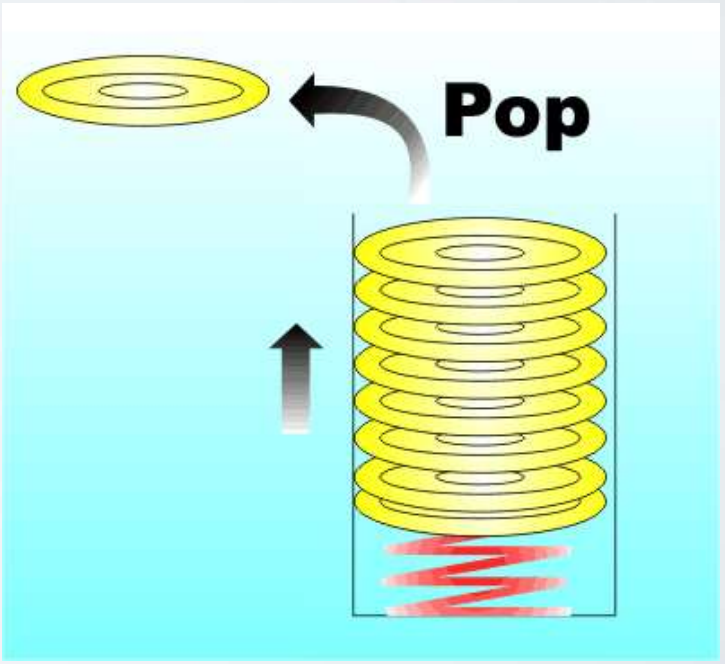
push(x): insereaza elementul *x in varful* stivei (en. *top, stack pointer*)

- Intrare: ElementStiva; Iesire: nimic



pop(): Sterge elementul aflat in varful stivei, si il returneaza; daca stiva e goala, mesaj de eroare

- Intrare: nimic; Iesire: ElementStiva



STIVA
OPERATII ADITIONALE

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- Utile dar nu fundamentale:
  - size(): returneaza numarul de elemente din stiva
    - Intrare: nimic; Iesire: intreg
  - isEmpty(): semnaleaza daca stiva este goala
    - Intrare: nimic; Iesire: boolean
  - top(): returneaza elementul din varful stivei, fara a-l sterge; daca stiva este goala, mesaj de eroare.
    - Intrare: nimic; Iesire: ElementStiva

STIVA: IMPLEMENTARE

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Pseudocod:

```
PUSH(S,p)
   S.top = S.top + 1
   S.[S.top] = p

POP(S)
   if S.top ==0
         error "underflow"
   else S.top = S.top - 1
   return S[S.top +1]
```

- Folosim o *lista inlantuita*
  - Simplu sau dublu inlantuita?
  - De cate referinte avem nevoie pentru a implementa eficient operatiile? (i.e. first si/sau last)
- Folosim un *vector*
- Overflow?

Sursa: Th. Cormen – "Introduction to Algorithms"

STIVA: IMPLEMENTARE CU LISTA SIMPLU INLANTUITA

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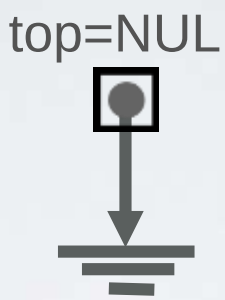
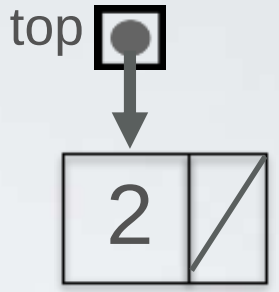
Echivalenta cu operatiile pe lista:

push = insert_first

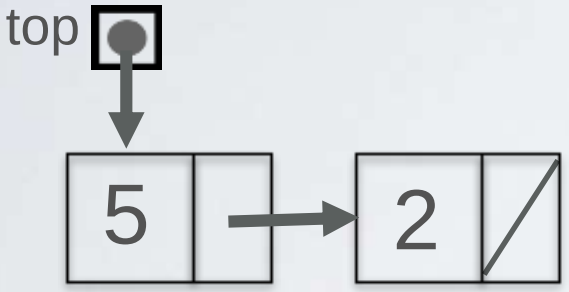
pop = delete_first



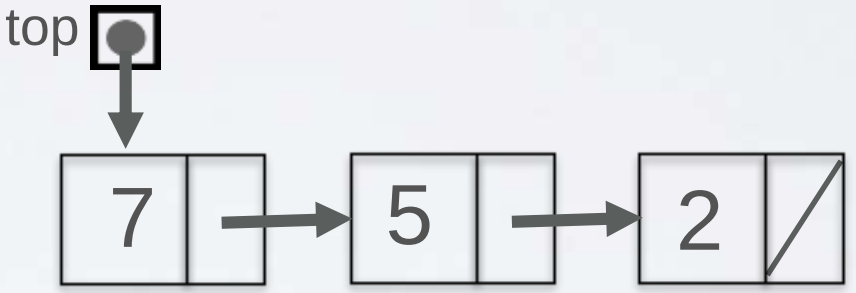
push(2)



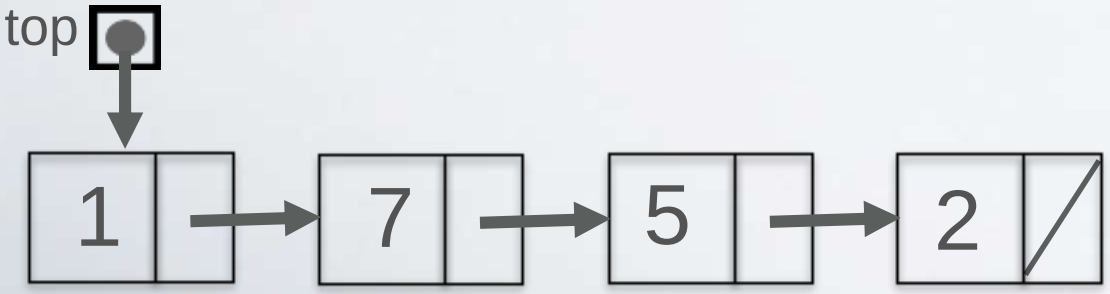
push(5)



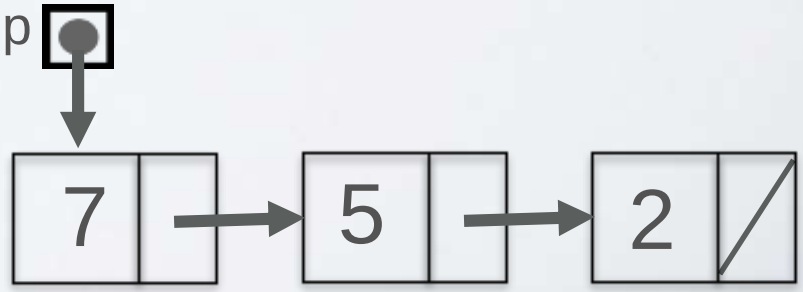
push(7)



push(1)



pop()



STIVA: IMPLEMENTARE CU VECTORI

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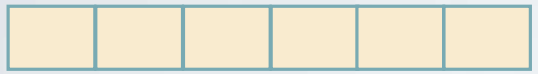
Definim un vector cu o capacitate data. Initial stiva e goala (i.e. Top = 0, Size = 0). Campul Size nu este necesar.



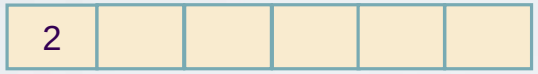
1 2 3 4 5 6

Top = 0;
Size = 0;
Capacity = 6;

```
//push(x)
top ++;
stiva[top] = x;
```

```
//pop
top--;
```

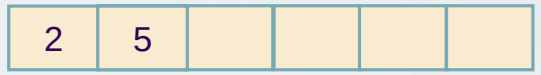
push(2)



1 2 3 4 5 6

Top = 1;
Size = 1;
Capacity = 6;

push(5)



1 2 3 4 5 6

Top = 2;
Size = 2;
Capacity = 6;

push(7)

1 2 3 4 5 6

Top = 3;
Size = 3;
Capacity = 6;

push(1)

1 2 3 4 5 6

Top = 4
Size = 4;
Capacity = 6;

pop()

1 2 3 4 5 6

Top = 3;
Size = 3;
Capacity = 6;

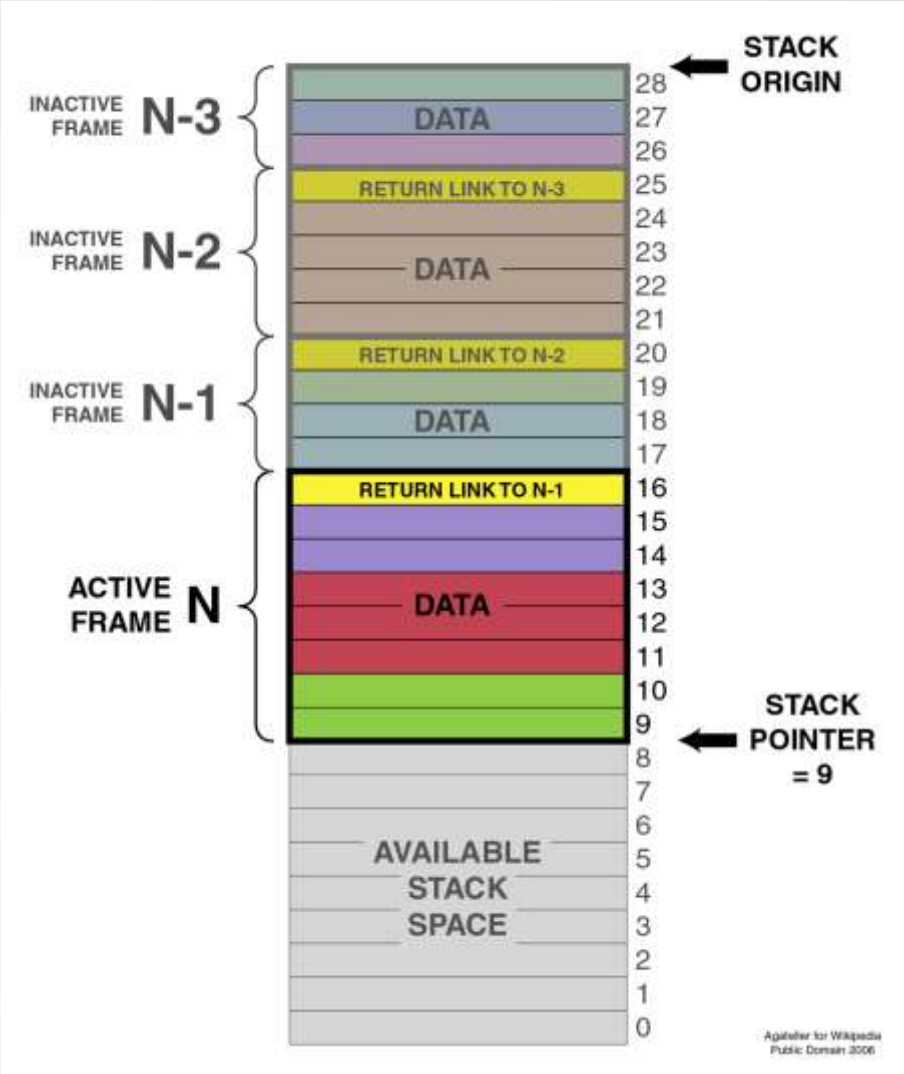
push(21)

1 2 3 4 5 6

Top = 4;
Size = 4;
Capacity = 6;

STIVA - UTILITATE

- Stiva apare in programe: *call stack*
  - Structura de date care stocheaza informatia despre subrutinele active ale unui program.
  - Mecanism cheie in apelul/iesirea functii/proceduri
  - Formata din *stack frames*
- Recursivitatea - stiva
  - Apel: push *stack frame*
  - Iesire: pop *stack frame*
  - *Stack frame*
    - argumente functie
    - variabile locale
    - adresa de iesire
- Evaluarea expresiilor
- Natural Language Processing
  - *Parsing* sintactic



COADA

Colectie de elemente cu politica de acces (inserare/stergere) de tip *FIFO* (*First-In-First-Out*)

- Elementele sunt inserate astfel incat, la orice moment, elementul care a fost inserat la cel mai indepartat moment poate fi eliminat (cel mai *vechi*)
- Inserare: la *sfarsit* (tail, rear) - *“enqueue”*
- Stergere: de la *inceput* (head, front) - *“dequeue”*

https://www.tutorialspoint.com/data_structures_algorithms/images/queue_example.jpg

COADA: OPERATII FUNDAMENTALE

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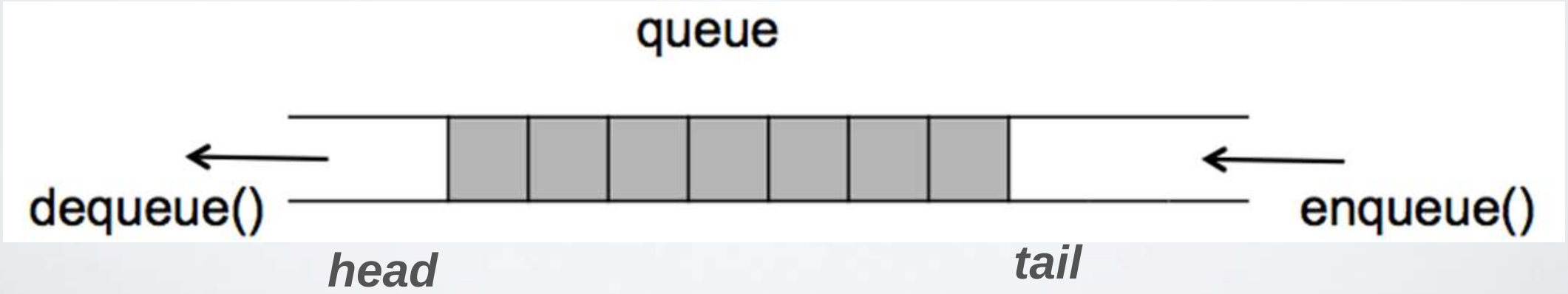
- Operatii fundamentale:
  - enqueue(elem): Insereaza elementul *elem* la sfarsitul cozii
    - Intrare: ElementCoada; Iesire: nimic
  - dequeue(): Sterge elementul aflat la inceputul cozii si il returneaza; eroare daca nu exista elemente in coada
    - Intrare: nimic; Iesire: ElementCoada



http://www.cs.cmu.edu/~mrmiller/15-121/Homework/hw8/queue.png

COADA: OPERATII ADITIONALE

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Operatii utile dar nu fundamentale:

- size(): returneaza numarul de elemente din coada
  - Intrare: nimic; Iesire: intreg
- isEmpty(): semnaleaza daca coada este goala
  - Intrare: nimic; Iesire: boolean
- front(): returneaza elementul din varful cozii, fara a-l sterge; daca coada este goala, mesaj de eroare.
  - Intrare: nimic; Iesire: ElementCoada

COADA: IMPLEMENTARE

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- Cum implementam o coada ?
  - Folosim o lista inlantuita
    - Simplu/dublu?
    - Cu first si last?
  - Cu sir

COADA: IMPLEMENTARE CU LISTE SIMPLU INLANTUITE

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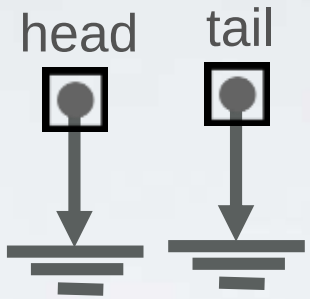
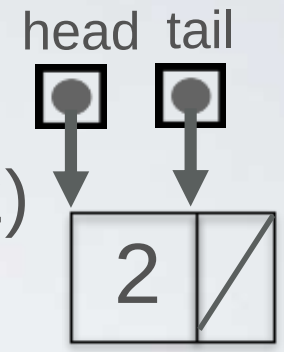
Echivalenta cu operatiile pe lista:

enqueue = insert_last

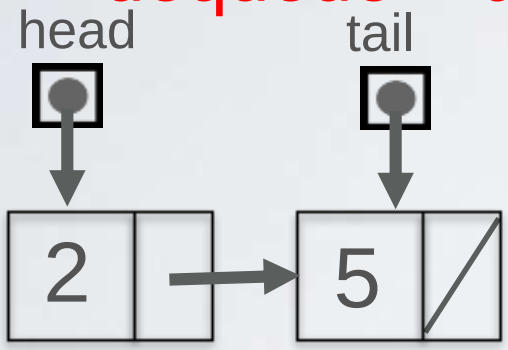
dequeue = delete_first



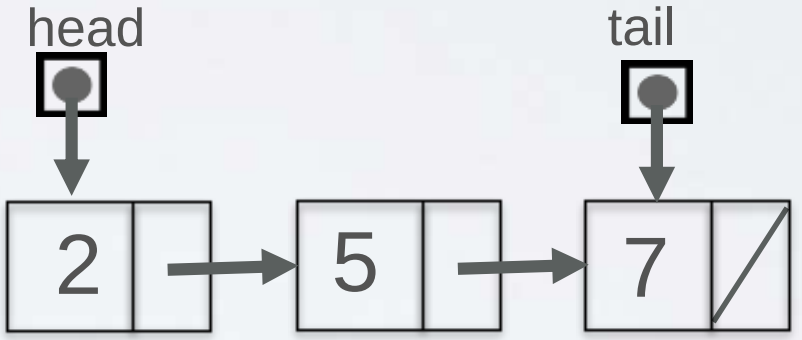
enqueue(2)



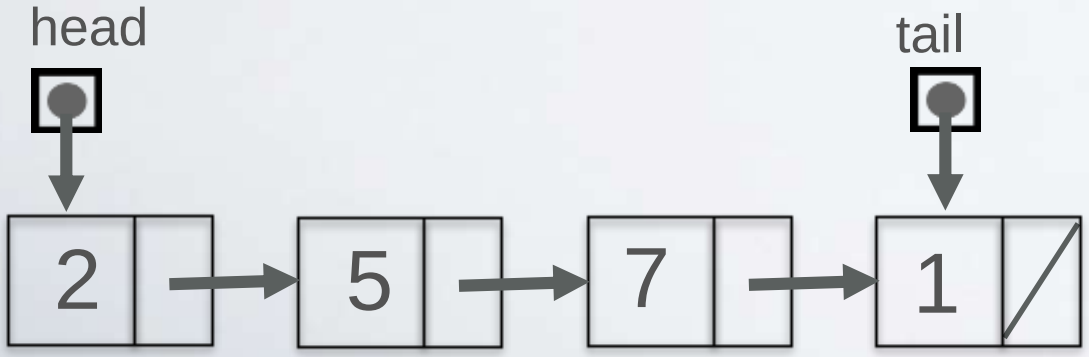
enqueue(5)



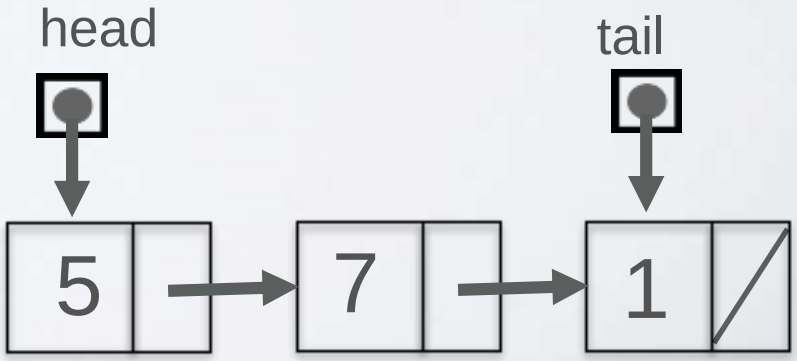
enqueue(7)



enqueue(1)

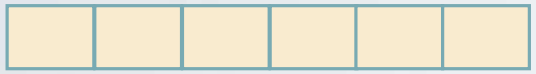


dequeue()



COADA: IMPLEMENTARE CU VECTOR

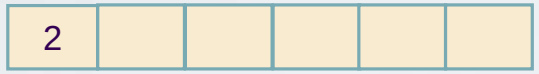
Definim un vector cu o capacitate data.



1 2 3 4 5 6

head= 0; tail= 0;
Size = 0;
Capacity = 6;

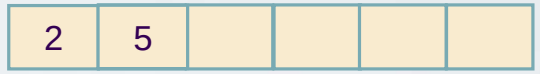
enqueue(2)



1 2 3 4 5 6

head=1; tail= 1;
Size = 1;
Capacity = 6;

enqueue(5)



1 2 3 4 5 6

head= 1; tail= 2;
Size = 2;
Capacity = 6;

enqueue(7)

1 2 3 4 5 6

head= 1; tail= 3;
Size = 3;
Capacity = 6;

enqueue:

Pas1 – Verificam daca coada este plina (size == capacity)

Pas 2 − Daca coada este plina trimitem mesaj de overflow si iesim.

Pas 3 − Daca coada nu este plina incrementam ultim ca sa “pointeze” la urmatorul spatiu liber (ultim ++);

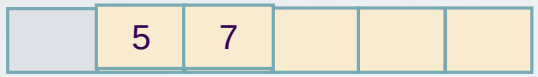
Pas 4 − Adaugam elementul pe pozitia lui ultim (coada[ultim] = x;)

Pas 5 − Returnam success !

COADA: IMPLEMENTARE CU VECTOR

head= 1; tail= 3;
Size = 3;
Capacity = 6;

dequeue()



head= 2; tail= 3;
Size = 2;
Capacity = 6;

enqueue(1)

head= 2; tail= 4;
Size = 3;
Capacity = 6;

dequeue()

head= 3; tail= 4;
Size = 2;
Capacity = 6;

dequeue:
Pas1 – Verificam daca coada este goala(size == 0)
Pas 2 − Daca coada este goala trimitem mesaj de underflow si iesim.
Pas 3 − Daca coada nu este goala incrementam prim ca sa “pointeze” la urmatorul spatiu liber (prim ++);
Pas 4 − Returnam success !

enqueue(20)

head= 3; tail= 5;
Size = 3;
Capacity = 6;

enqueue(17)

head= 3; tail= 6;
Size = 4;
Capacity = 6;

enqueue(30) – ce se intampla?

COADA ***CIRCULARA***: IMPLEMENTARE CU VECTOR

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Pseudocod:

```
ENQUEUE(Q, p)
  Q[Q.tail] = p
  if Q.tail == Q.capacity
        Q.tail = 1
  else Q.tail = Q.tail + 1
```

enqueue(30)

30		7	3	20	17
1	2	3	4	5	6

head= 3; tail= 1;
Size = 5;
Capacity = 6;

enqueue(10)

30	10	7	3	20	17
1	2	3	4	5	6

head=3; tail= 2;
Size = 6;
Capacity = 6;

Overflow/underflow??

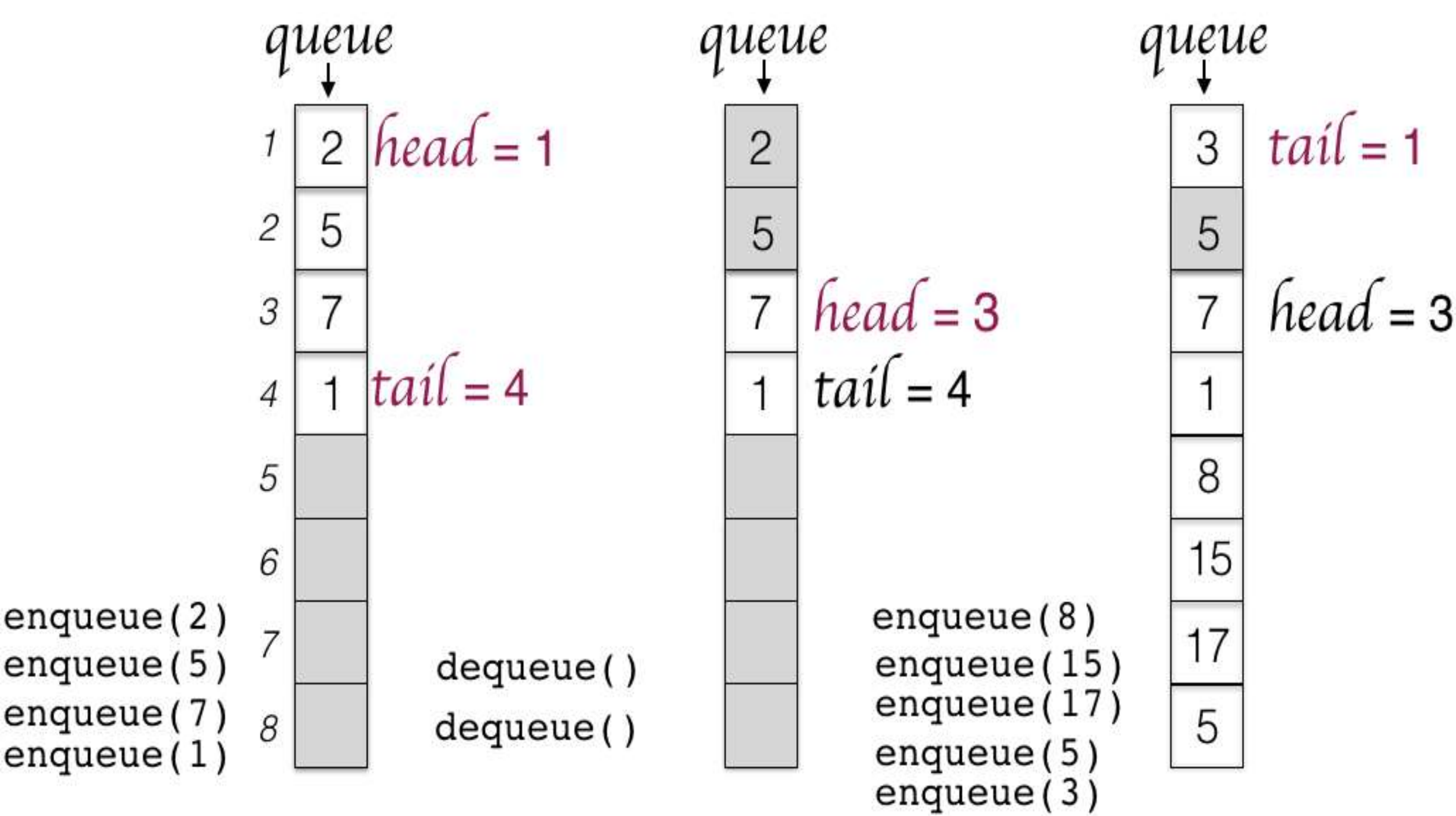
```
DEQUEUE()
  p = Q[Q.head]
  if Q.head == Q.capacity
        Q.head = 1
  else Q.head = Q.head + 1
  return p
```

dequeue()

30	10		3	20	17
1	2	3	4	5	6

head= 4; tail= 2;
Size = 5;
Capacity = 6;

Sursa: Th. Cormen – "Introduction to Algorithms"


queue
1
2
3
4
5
6
7
8
2
5
7
1
head = 1
tail = 4
enqueue(2)
enqueue(5)
enqueue(7)
enqueue(1)
dequeue()
dequeue()
queue
2
5
7
1
head = 3
tail = 4
enqueue(8)
enqueue(15)
enqueue(17)
enqueue(5)
enqueue(3)
queue
3
5
7
1
8
15
17
5
tail = 1
head = 3

COADA CIRCULARA

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- Structura liniara in care operatiile sunt efectuate conform principiului FIFO dar ultimul element este conectat la primul element si formeaza astfel o structura circulara.
- Poate fi implementata folosind:
  - Liste simplu/dublu inlantuite
  - Vectori
- Utilitate
  - *Round Robin* – algoritm de planificare pentru resursele CPU

COADA – UTILITATE

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- Scheduler (e.g. in sistemul de operare), pentru mentinerea ordinii de acces la resursele partajate
  - Printer scheduling
  - CPU scheduling (coada circulara)
  - Disk scheduling
- Transfer asincron de date
  - Buffere I/O, *pipes*, citire/scriere in fisiere

BIBLIOGRAFIE

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- Th. Cormen et al – “Introduction to Algorithms”, 3rd ed: sect. 10.1, 10.2
- https://www.doc.ic.ac.uk/~ar3/lectures/ProgrammingII/L3/Unit3Stacks&QueuesTwoUp.pdf