

Bases de Datos

Clase 8: Evaluación de consultas

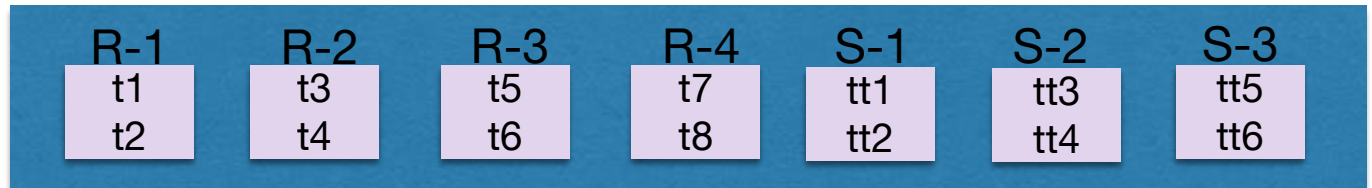
Páginas, disco y buffer

Para trabajar con las tuplas de una relación, la base de datos carga la página desde el disco con dicha tupla

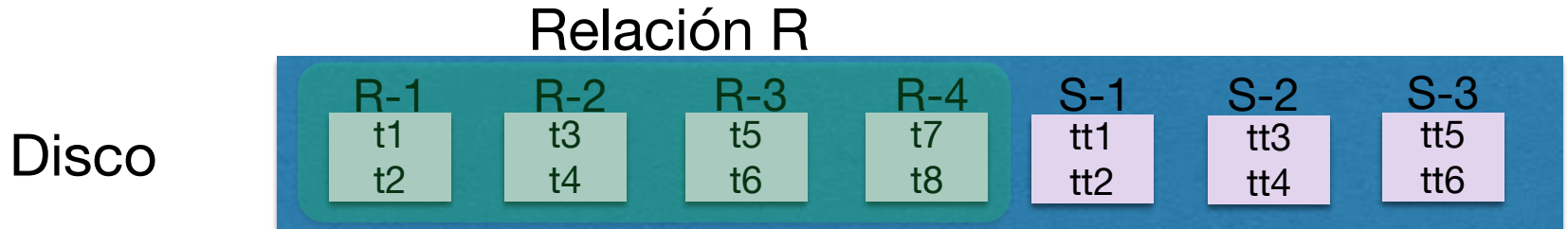
Para cargar estas páginas, la base de datos reserva un espacio en RAM llamado **Buffer**

Páginas, disco y buffer

Disco

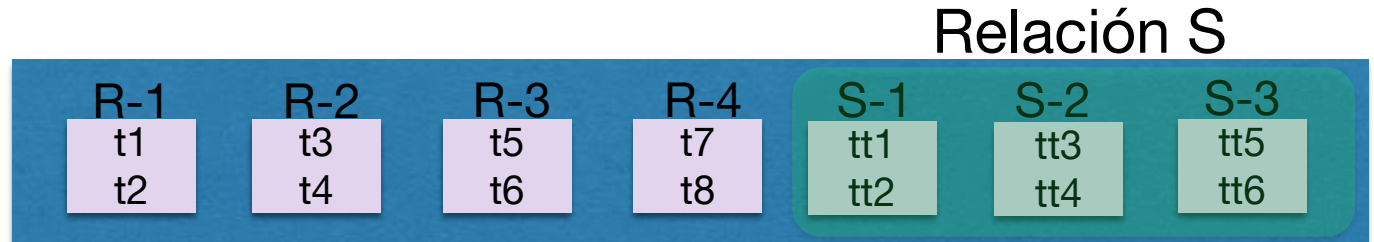


Páginas, disco y buffer



Páginas, disco y buffer

Disco

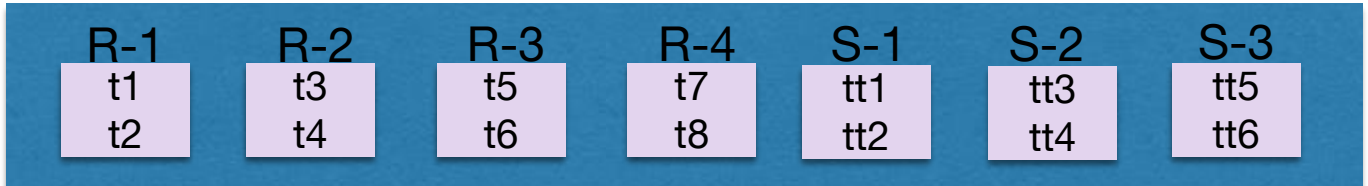


Páginas, disco y buffer

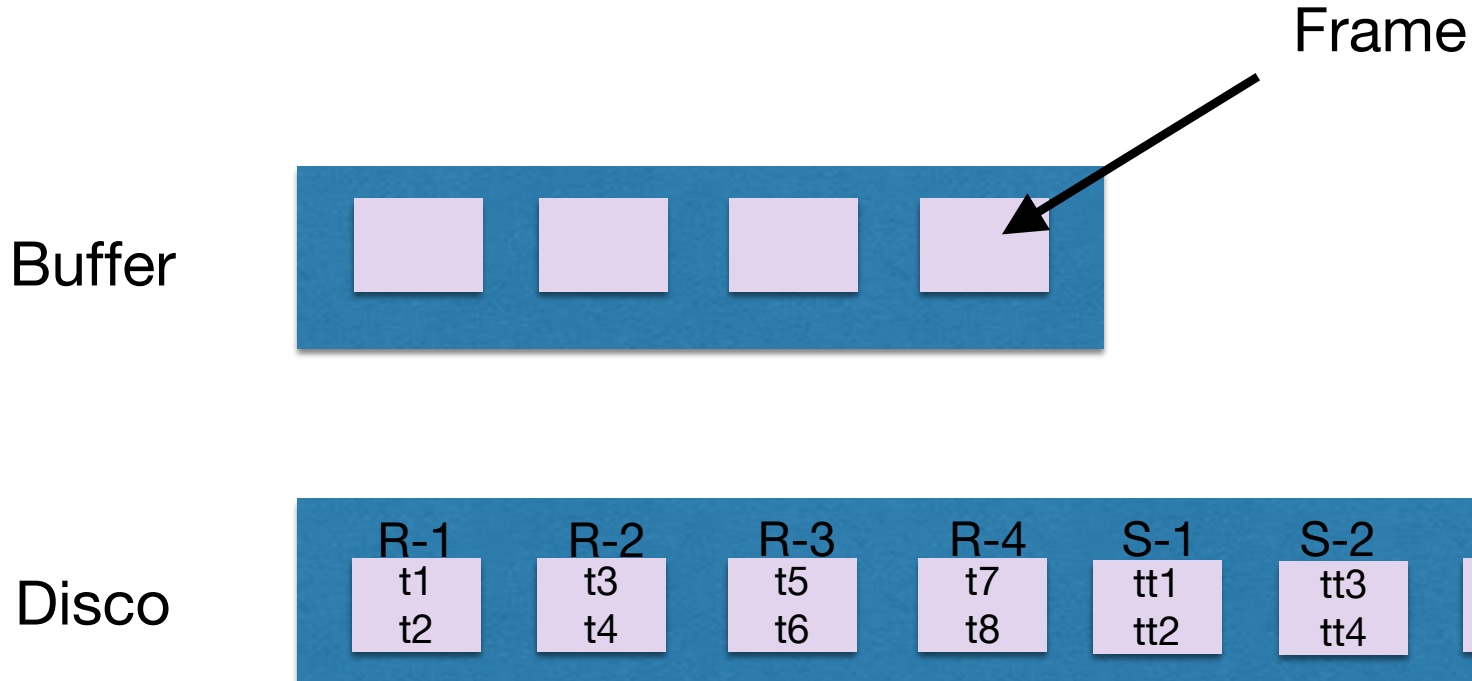
Buffer



Disco



Páginas, disco y buffer

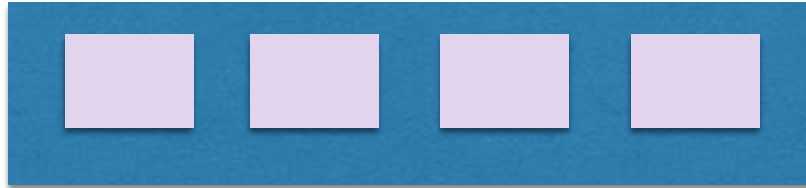


Páginas, disco y buffer

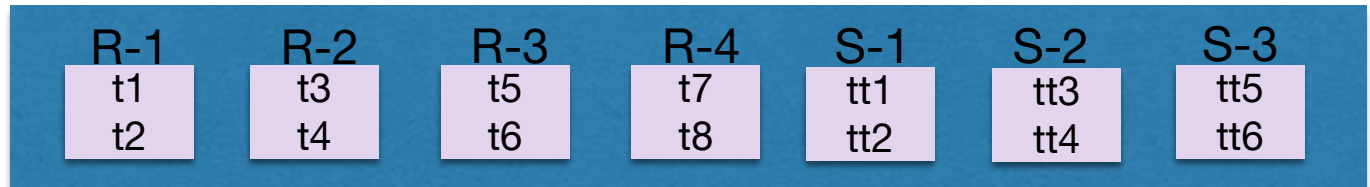
DB

Necesito tupla t3 de R!

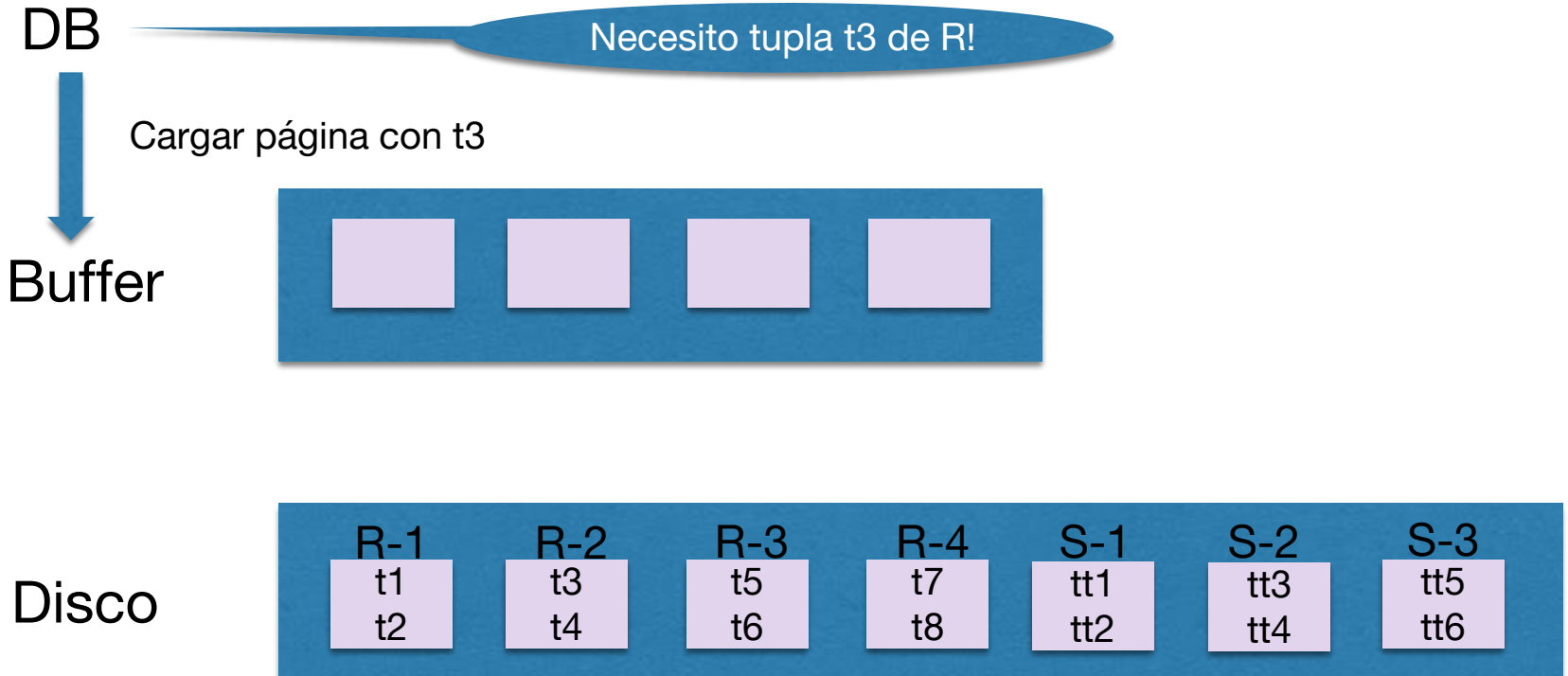
Buffer



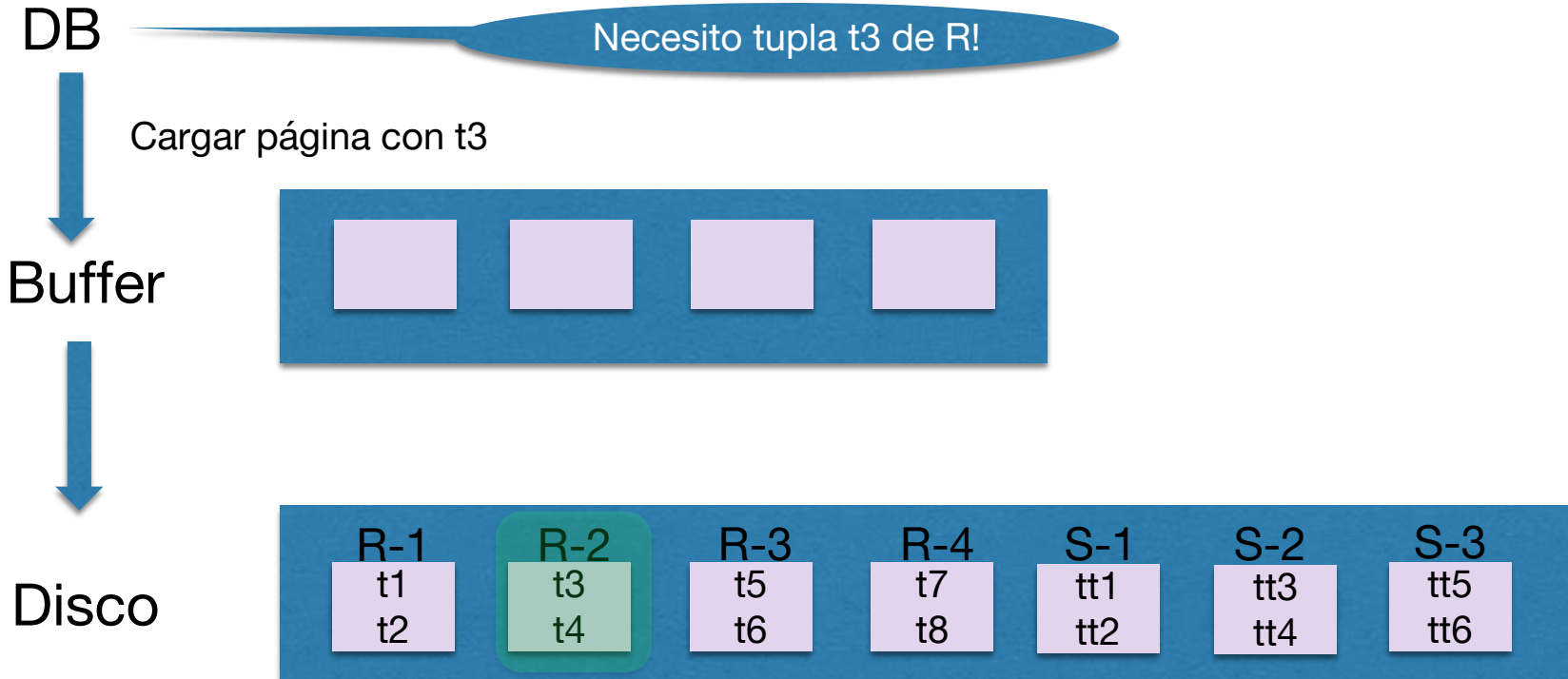
Disco



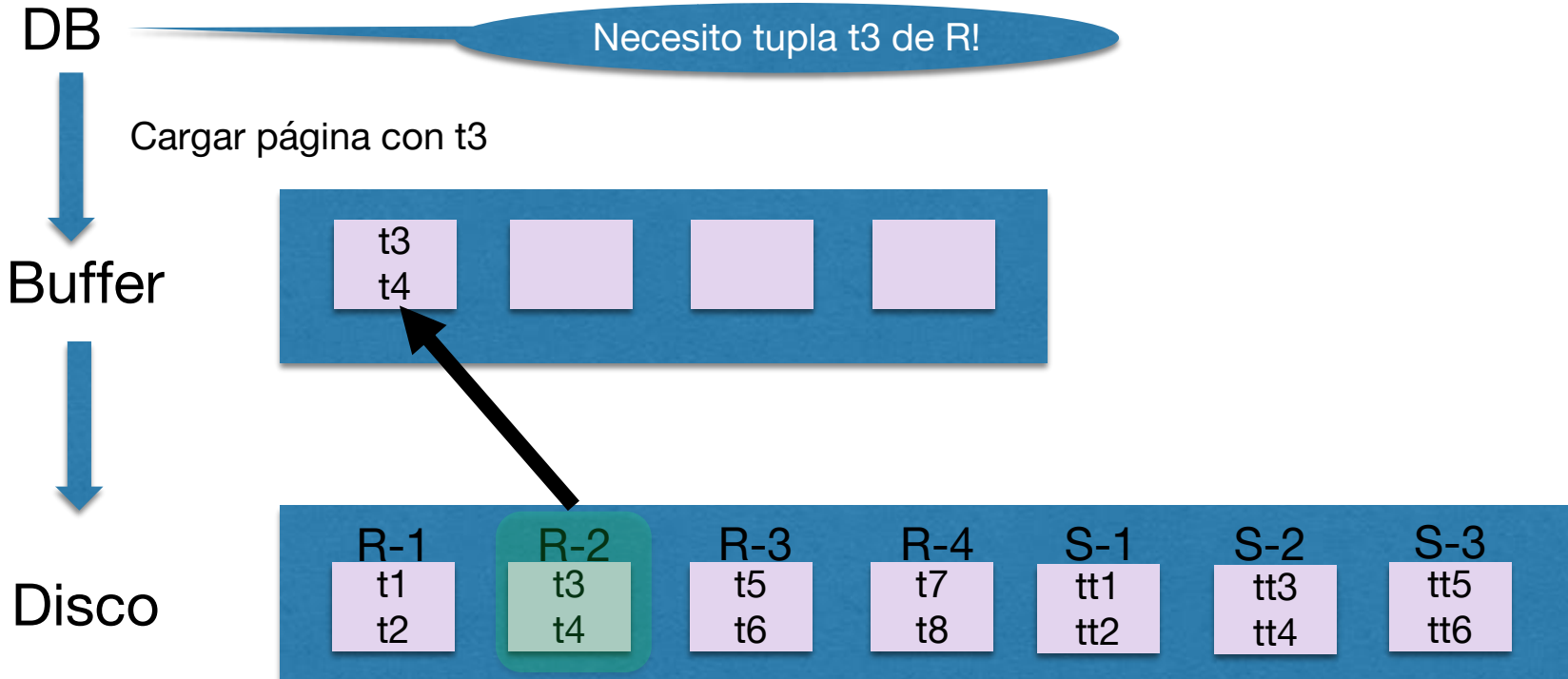
Páginas, disco y buffer



Páginas, disco y buffer



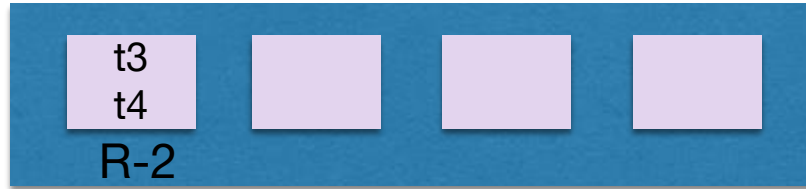
Páginas, disco y buffer



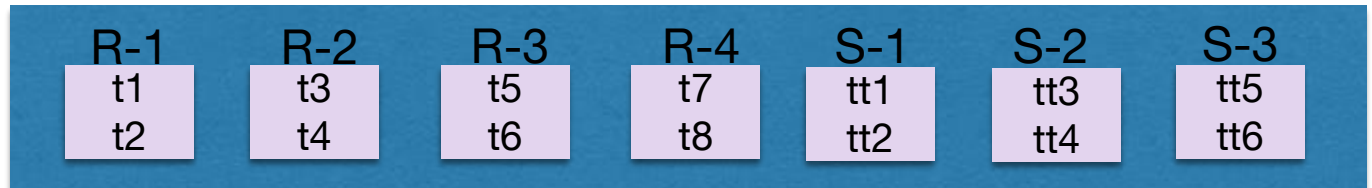
Páginas, disco y buffer

DB

Buffer



Disco

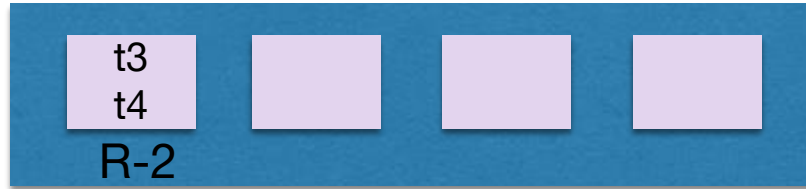


Páginas, disco y buffer

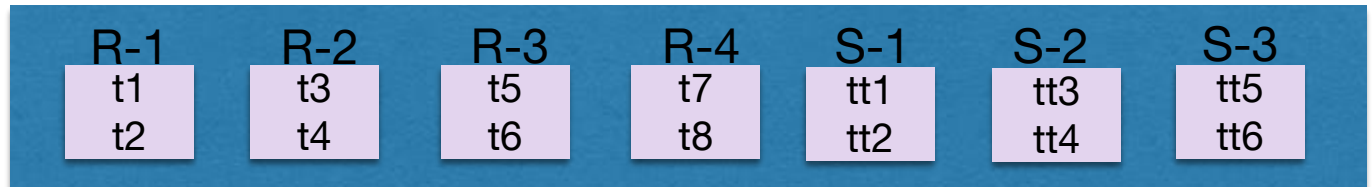
DB

Necesito tupla t4 de R!

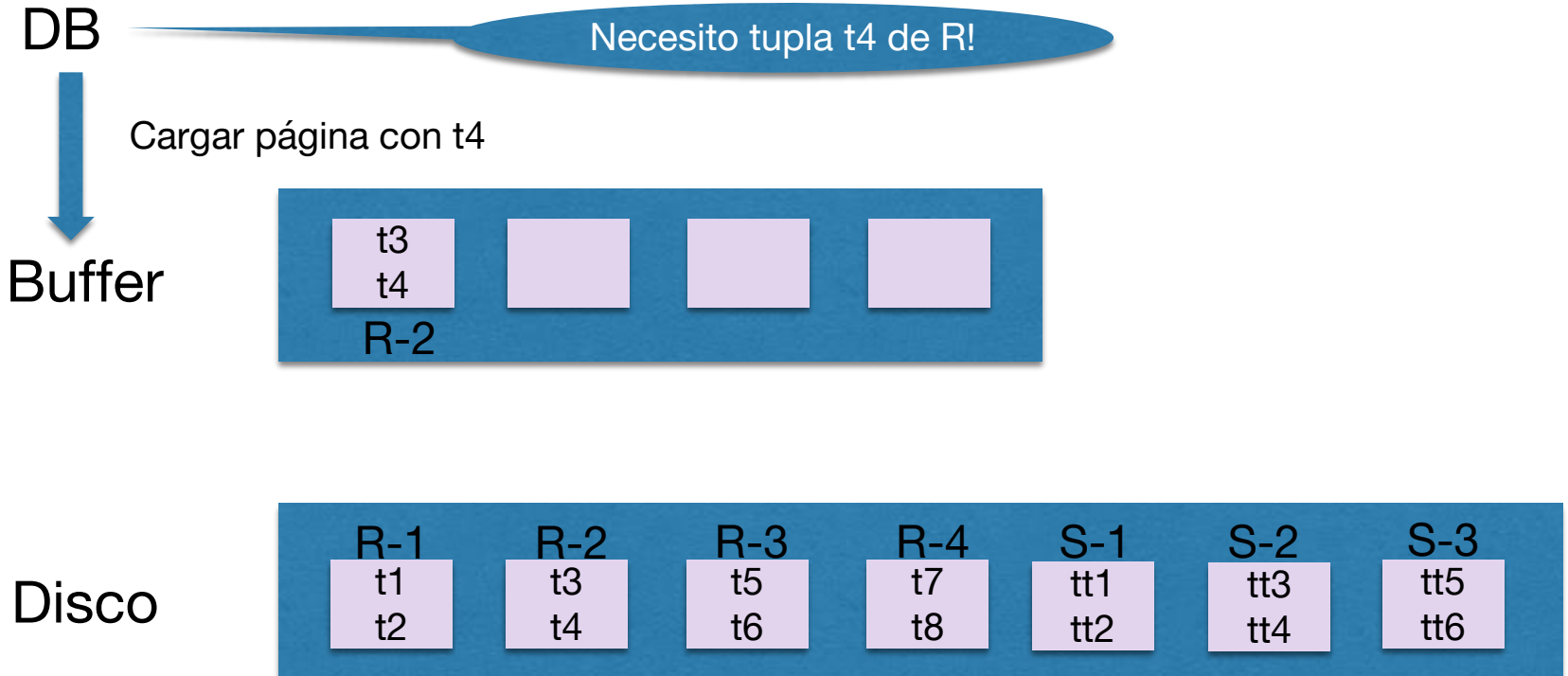
Buffer



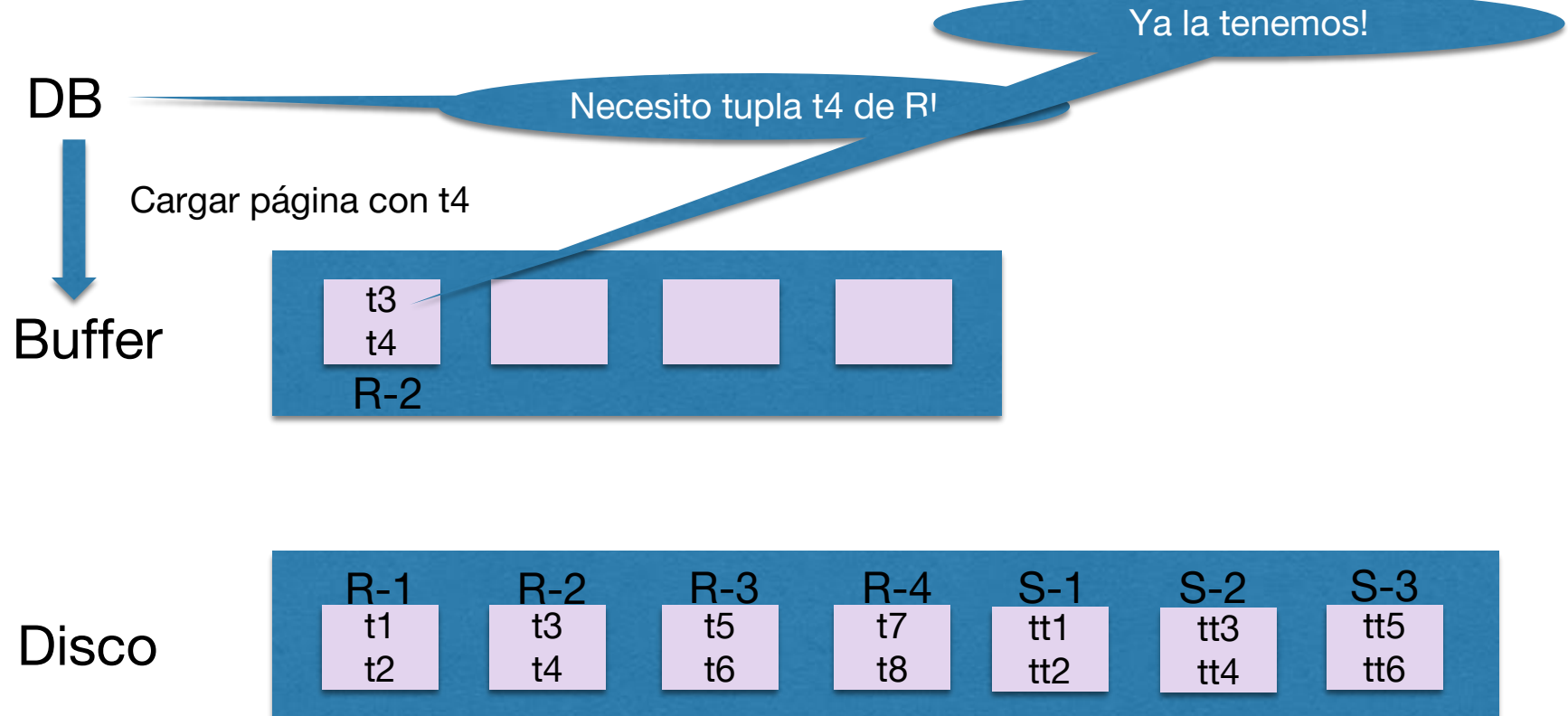
Disco



Páginas, disco y buffer



Páginas, disco y buffer



Costo de un algoritmo

Cuántas veces tengo que leer una página desde el disco, o escribir una página al disco!

Las operaciones en buffer (RAM) son orden(es) de magnitud más rápidas que leer/escribir al disco – costo 0

Algoritmos en una BD

Implementan interfaz de un iterador lineal:

- `open()`
- `next()`
- `close()`

Algoritmos en una BD

Para una relación R:

- R.open() – se posiciona **antes** de la primera tupla de R
- R.next() – devuelve la siguiente tupla o NULL
- R.close() – cierra el iterador

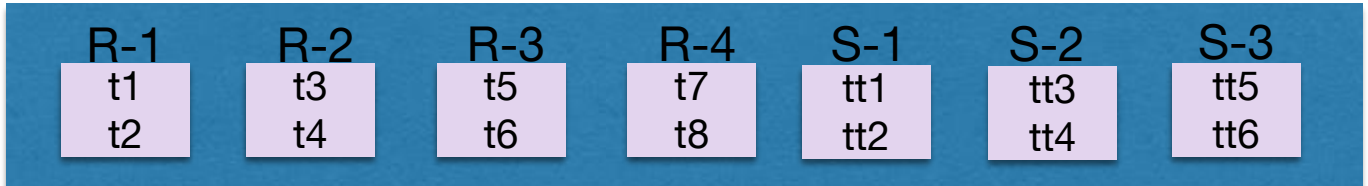
Páginas, disco y buffer

DB

Buffer



Disco

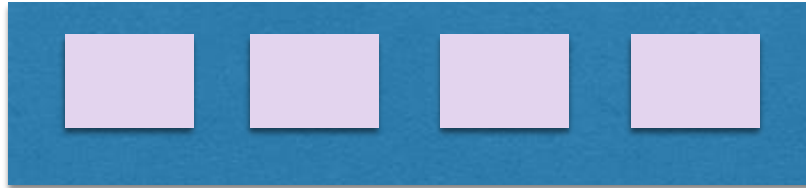


Páginas, disco y buffer

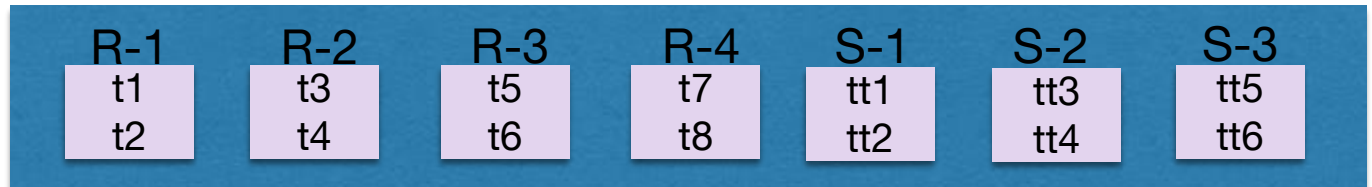
DB

R.open()

Buffer



Disco

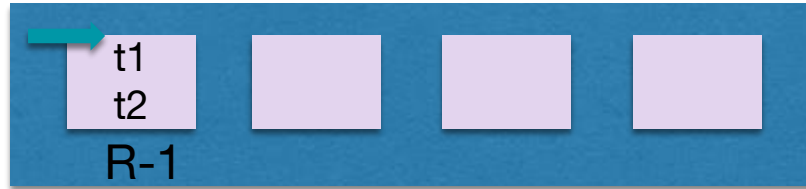


Páginas, disco y buffer

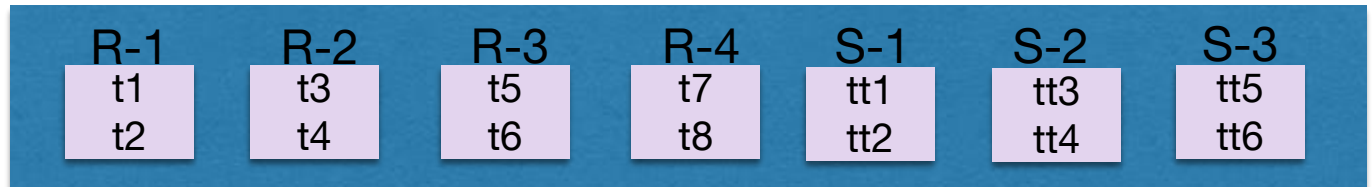
DB

R.open()

Buffer



Disco



Páginas, disco y buffer

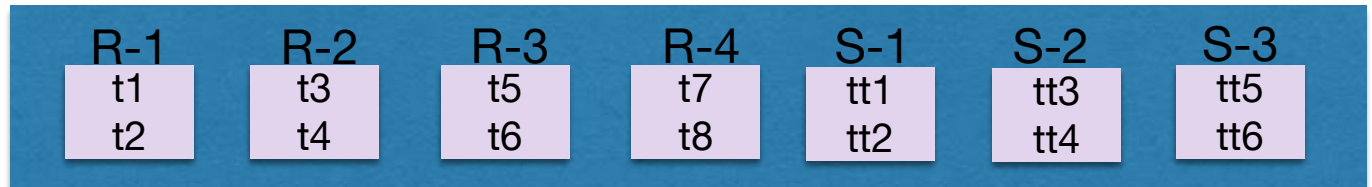
DB

R.next()

Buffer



Disco

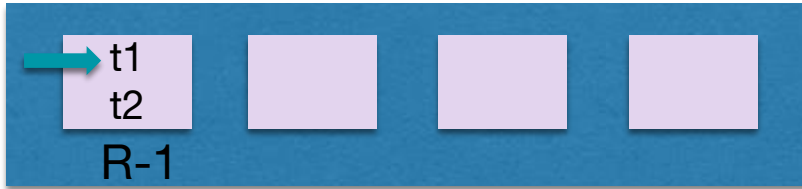


Páginas, disco y buffer

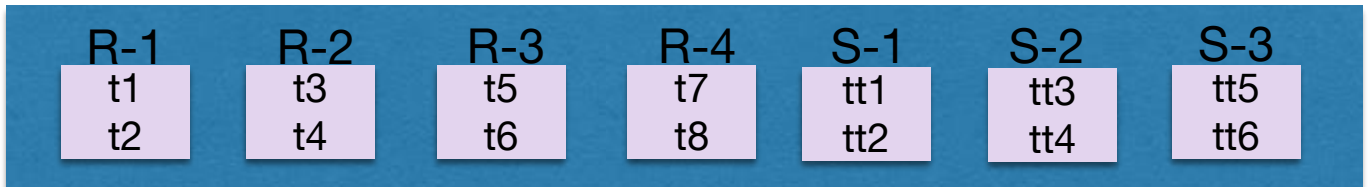
DB

R.next()

Buffer



Disco



Páginas, disco y buffer

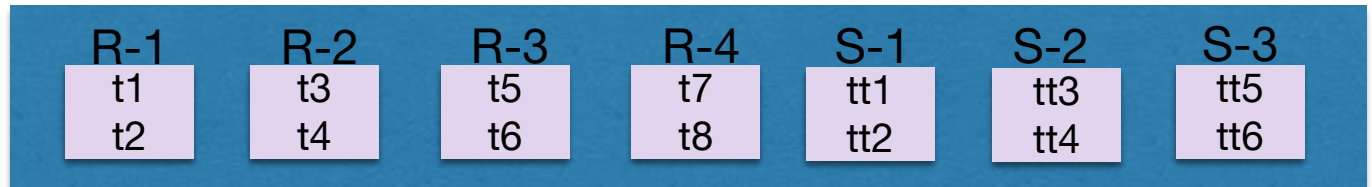
DB

R.next()

Buffer



Disco

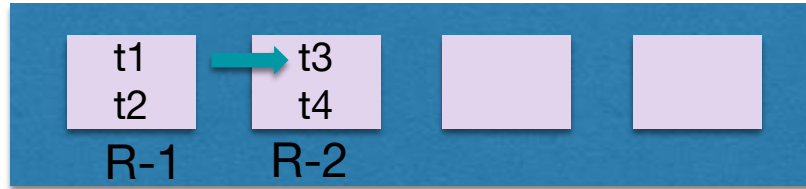


Páginas, disco y buffer

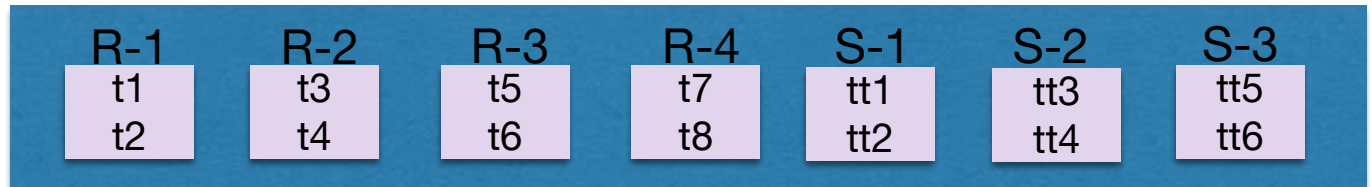
DB

R.next()

Buffer



Disco

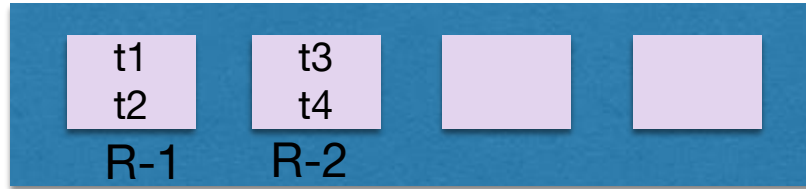


Páginas, disco y buffer

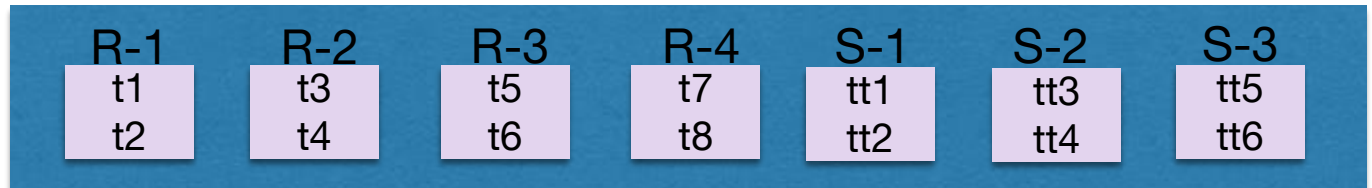
DB

R.close()

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

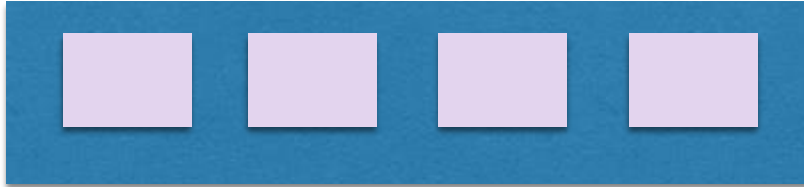
```
t:= R.next()
```

```
while t != null do  
    output t
```

```
t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

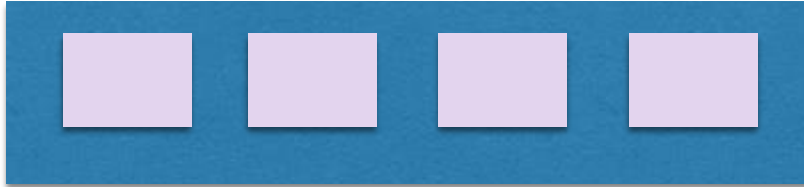
DB

R.open()

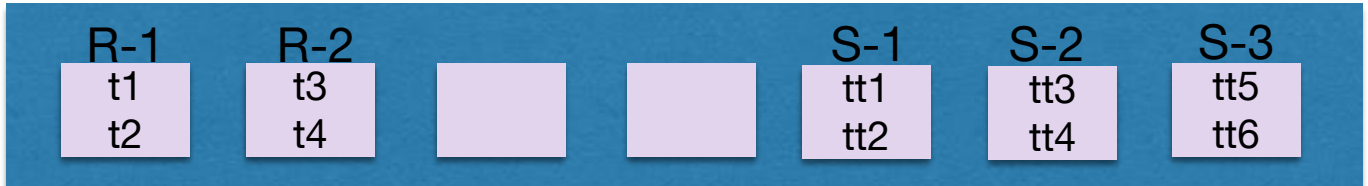
```
t:= R.next()  
while t != null do  
    output t  
    t:= R.next()
```

R.close()

Buffer



Disco



SELECT * FROM R

DB

R.open()

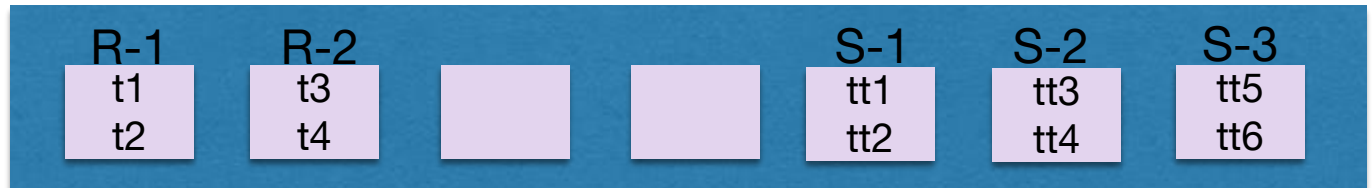
```
t:= R.next()  
while t != null do  
    output t  
    t:= R.next()
```

R.close()

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

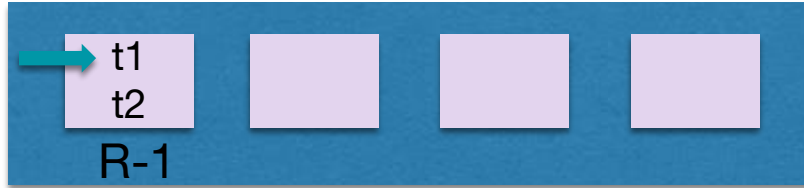
```
t := R.next()
```

```
while t != null do  
    output t
```

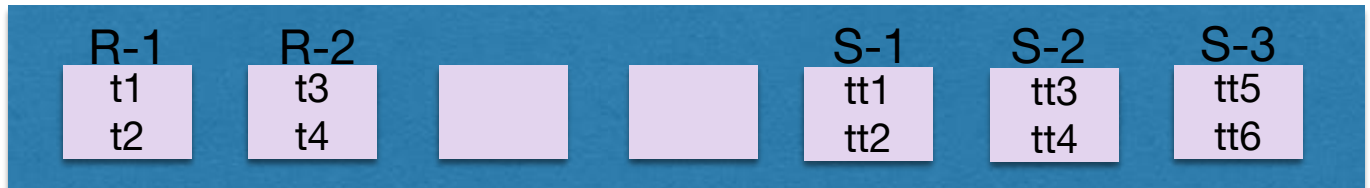
```
t := R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

```
t:= R.next()
```

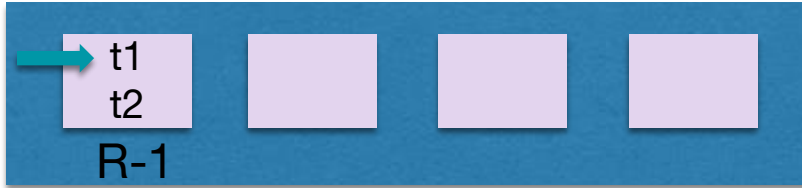
```
while t != null do
```

```
    output t
```

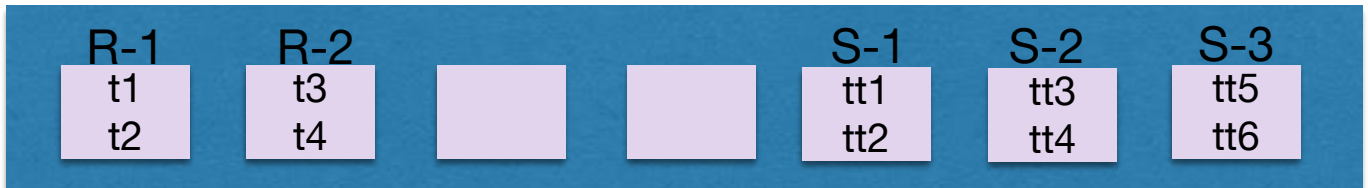
```
    t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

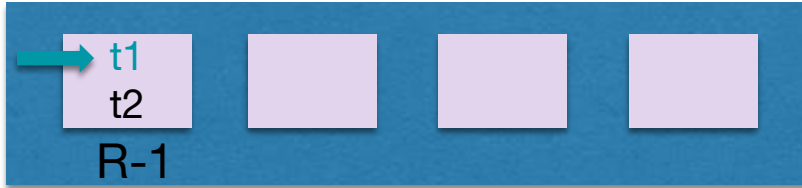
```
t:= R.next()
```

```
while t != null do  
    output t
```

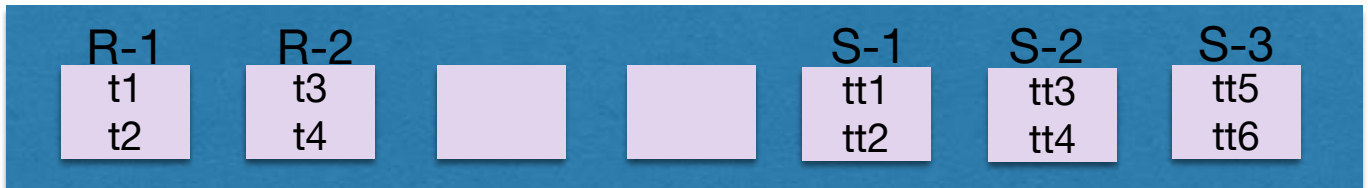
```
t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

```
t:= R.next()
```

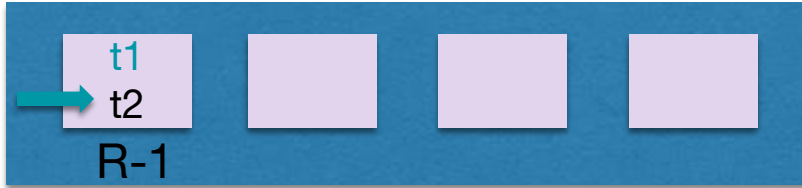
```
while t != null do
```

```
    output t
```

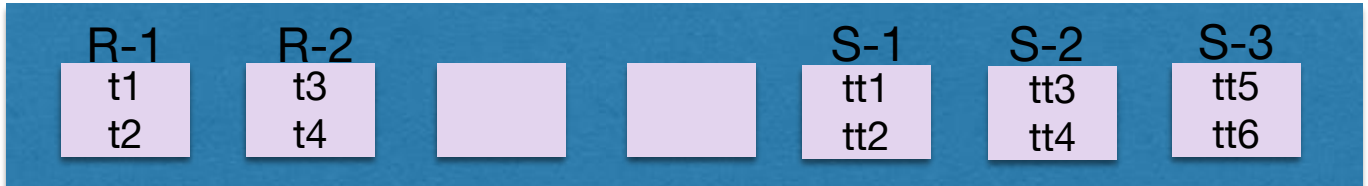
```
    t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

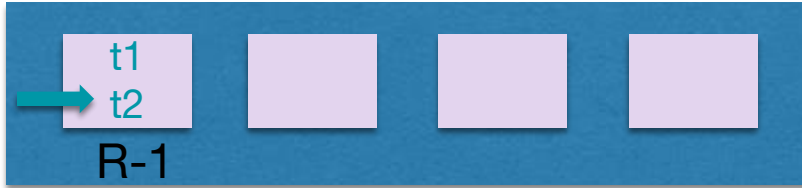
```
t:= R.next()
```

```
while t != null do  
    output t
```

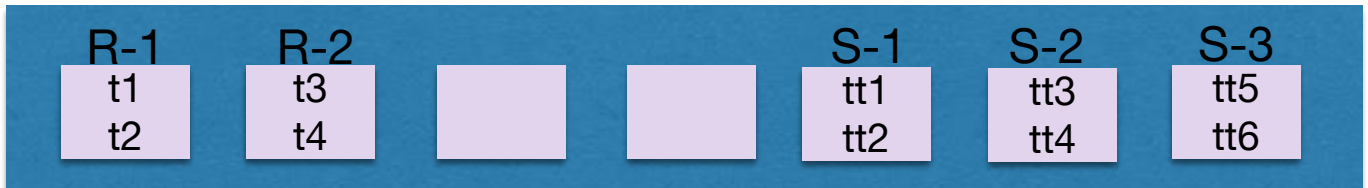
```
t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

```
t:= R.next()
```

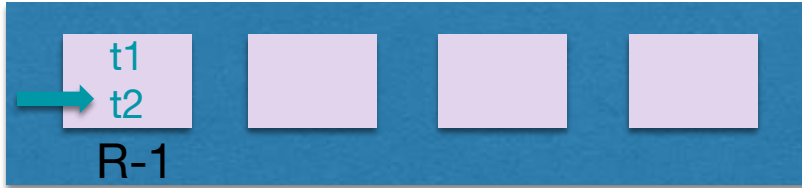
```
while t != null do
```

```
    output t
```

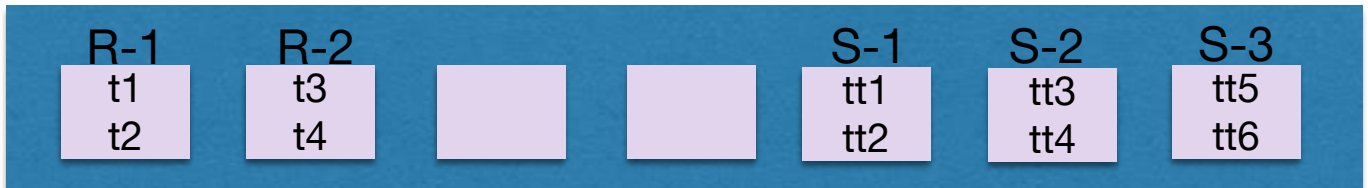
```
    t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

```
t:= R.next()
```

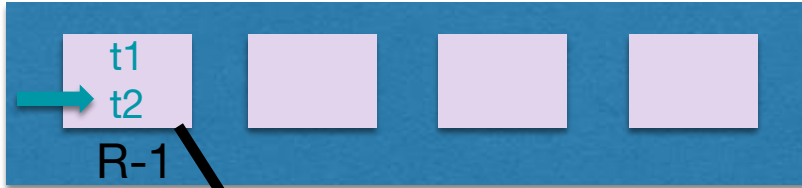
```
while t != null do
```

```
    output t
```

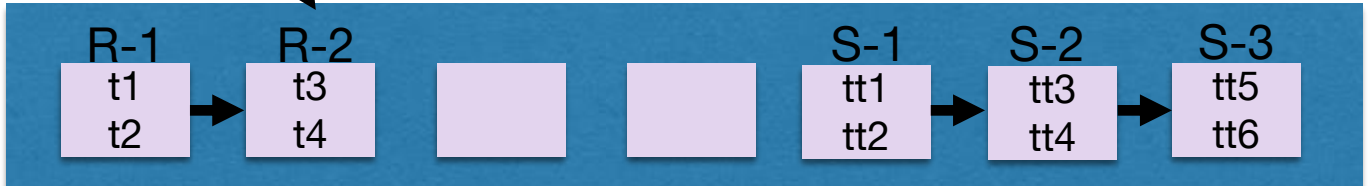
```
    t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

```
t:= R.next()
```

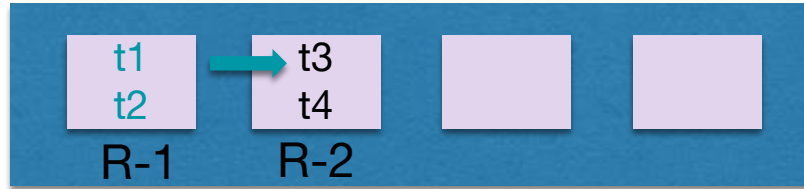
```
while t != null do
```

```
    output t
```

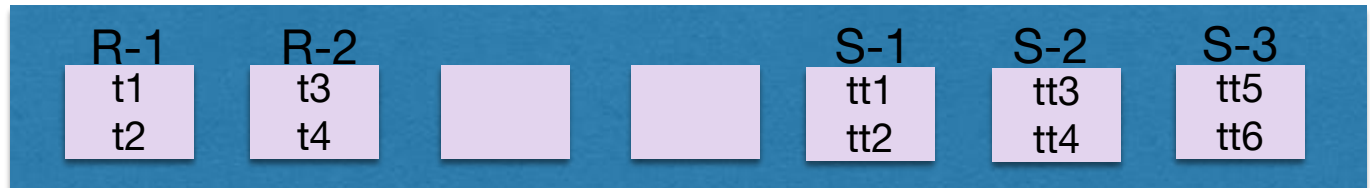
```
    t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

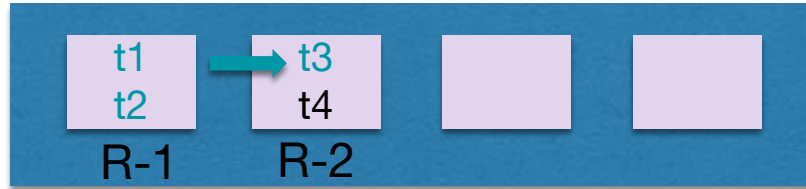
```
t:= R.next()
```

```
while t != null do  
    output t
```

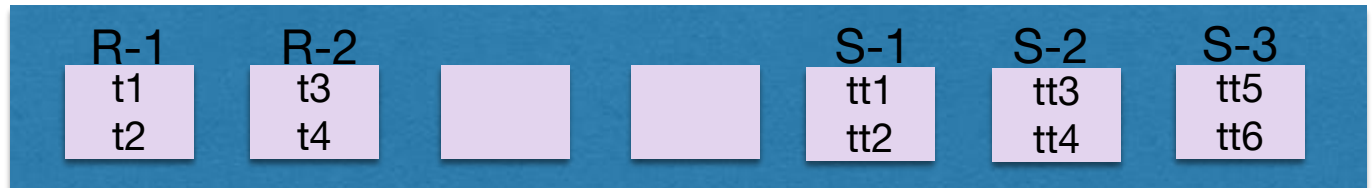
```
t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

```
t:= R.next()
```

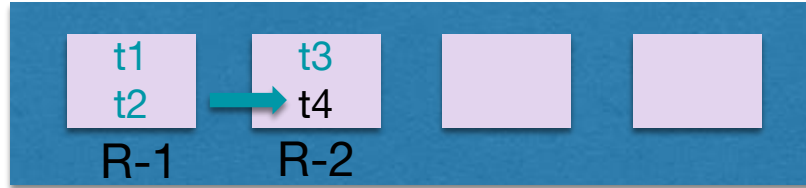
```
while t != null do
```

```
    output t
```

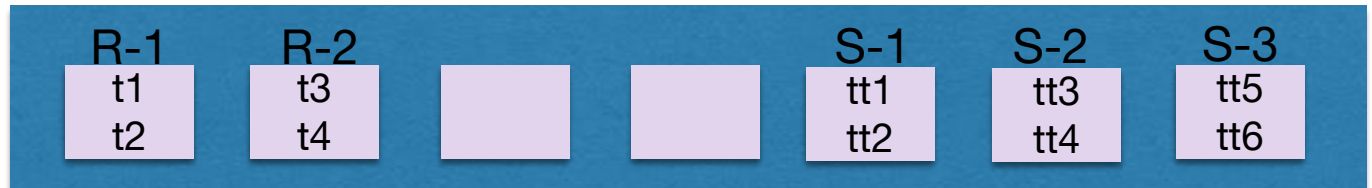
```
    t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

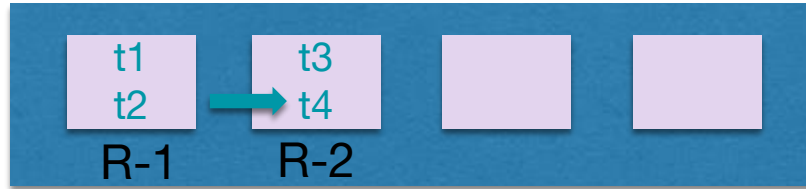
```
t:= R.next()
```

```
while t != null do  
    output t
```

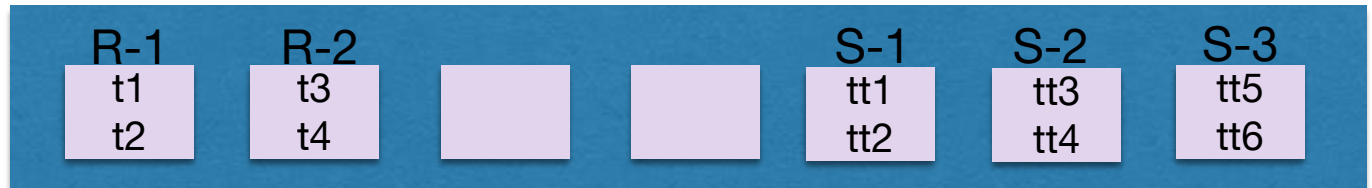
```
t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

DB

```
R.open()
```

```
t:= R.next()
```

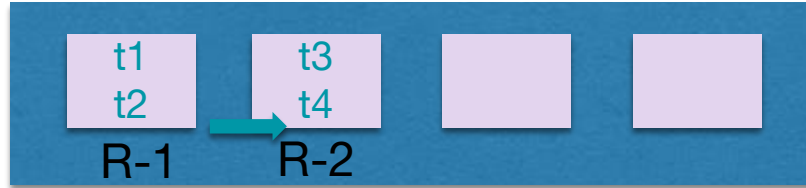
```
while t != null do
```

```
    output t
```

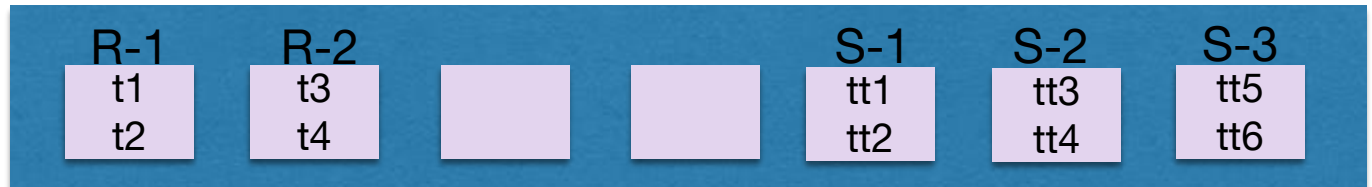
```
    t:= R.next()
```

```
R.close()
```

Buffer



Disco



SELECT * FROM R

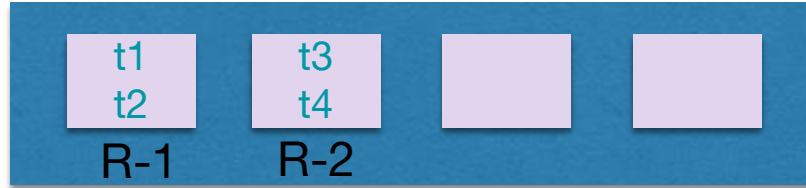
DB

```
R.open()
```

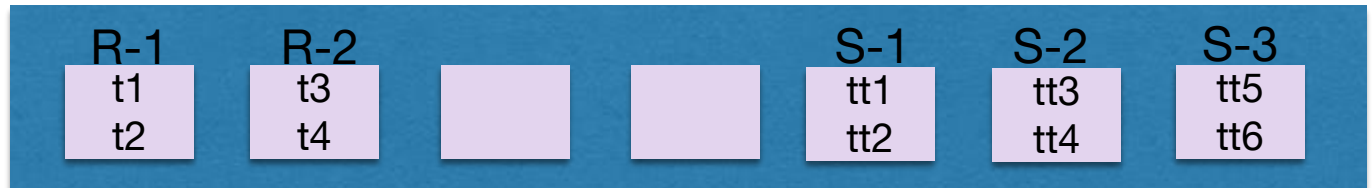
```
t:= R.next()  
while t != null do  
    output t  
    t:= R.next()
```

```
R.close()
```

Buffer



Disco



En realidad

Cada operador de algebra relacional implementa interfaz de un iterador lineal:

- `open()`
- `next()`
- `close()`

Selección

El algoritmo de selección cambia dependiendo si es una consulta de igualdad (=) o de rango (<, >)

También depende si el atributo a seleccionar está indexado

Implementa interfaz de iterador lineal

Selección

Sin índice

Si queremos hacer una selección sobre una tabla R

```
open()
  R.open()

next() // retorna el siguiente seleccionado
  t:= R.next()
  while t != null do
    if t satisface condición then
      return t
    t:= R.next()
  return null
```

Selección

Sin índice

Si queremos hacer una selección sobre una tabla **R**

```
open()
```

```
  R.open()
```

```
next() // retorna el siguiente seleccionado
```

```
  t:= R.next()
```

```
  while t != null do
```

```
    if t satisface condición then
```

```
      return t
```

```
      t:= R.next()
```

```
  return null
```

```
close()
```

```
  R.close()
```

Para recorrer la selección $Sel = \sigma_{cond}(R)$

```
Sel.open()
```

```
t := Sel.next()
```

```
while t != null do
```

```
  output t
```

```
  t:= Sel.next()
```

```
Sel.close()
```

Selección

Sin índice

Necesariamente tenemos que recorrer todo **R**

Selección

Con índice y consulta de igualdad

Si queremos hacer una selección sobre una tabla **R** a un atributo indexado con un índice **I**

```
open()  
  I.open()  
  I.search(Atributo = valor)
```

```
next()  
  t:= I.next()  
  while t != null do  
    return t  
  return null
```

```
close()  
  I.close()
```


Selección

Con índice y consulta de igualdad

Sólo tenemos que leer las páginas que satisfacen la condición (más I/O si muchas tuplas satisfacen la condición)

Cambia un poco si el índice es Clustered o Unclustered (¿Por qué?)

Si el atributo es llave primaria entonces la operación prácticamente tiene $I/O \sim 1$

Selección

Con índice y consulta de rango

¿Cómo podemos hacer este tipo de consultas de forma eficiente?

Hint Existe un índice especial para hacer esto

Proyección

Algoritmo muy sencillo

open()

 R.open()

next()

 t:= R.next()

while t != null **do**

return project(t, atributos)

return null

close()

 R.close()

Proyección

Necesariamente tenemos que recorrer todo **R**

Joins

Operación muy costosa

Supondremos solamente restricciones de igualdad (por ejemplo, $R.a = S.a$)

Nested Loop Join

Queremos hacer un join entre **R** y **S**, cuando se satisface un predicado **p**

```
open()  
  R.open()  
  S.open()  
  r:= R.next()
```

```
close()  
  R.close()  
  S.close()
```

Nested Loop Join

Queremos hacer un join entre **R** y **S**, cuando se satisface un predicado **p**

next()

```
while r != null do  
    s := S.next()  
    if s == null then  
        S.close()  
        r := R.next()  
        S.open()  
    else if (r, s) satisfacen p then  
        return (r, s)  
return null
```

Nested Loop Join

DB

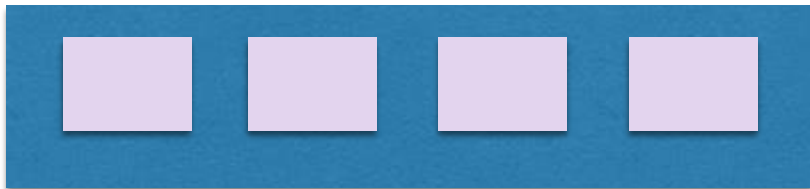
$$\text{Join} = R \bowtie_p S$$

Join.open()

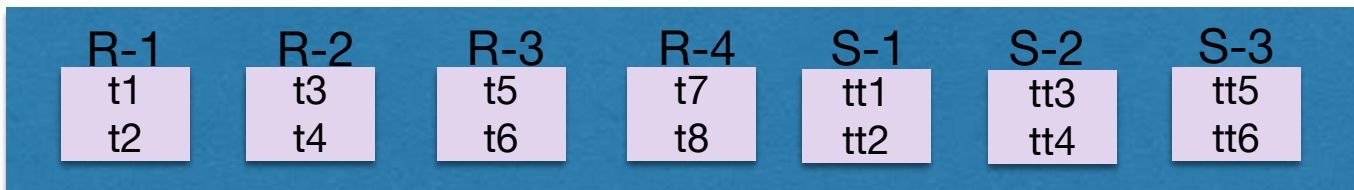
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

Join.close()

Buffer



Disco



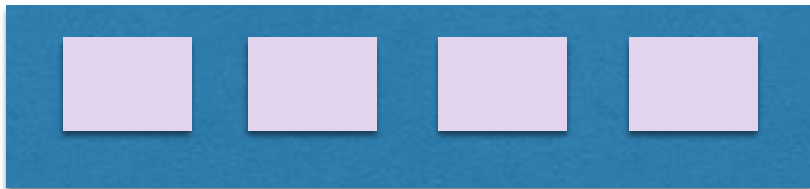
Nested Loop Join

DB

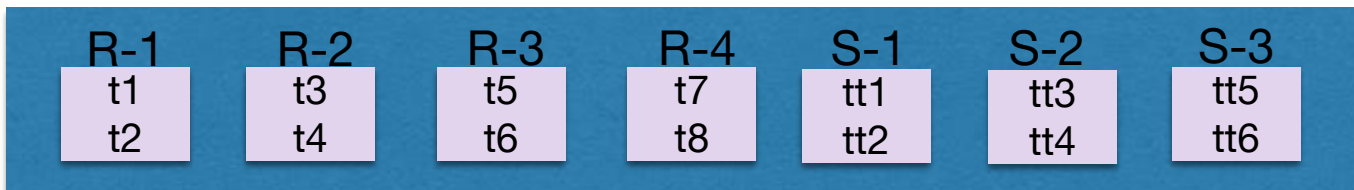
$R \bowtie_p S \dots \text{Join.open}()$

```
R.open()  
S.open()  
r := R.next()
```

Buffer



Disco



Nested Loop Join

DB

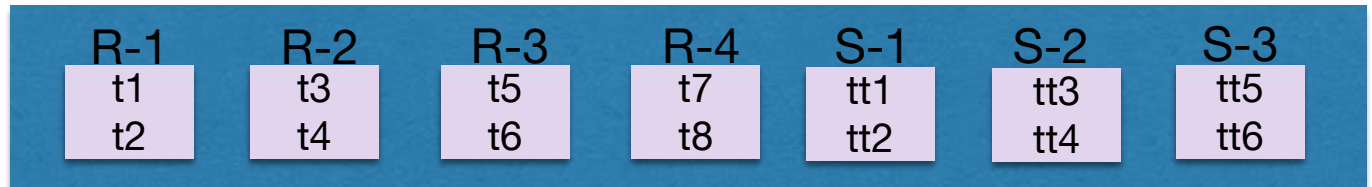
$R \bowtie_p S \dots \text{Join.open}()$

```
R.open()  
S.open()  
r := R.next()
```

Buffer



Disco



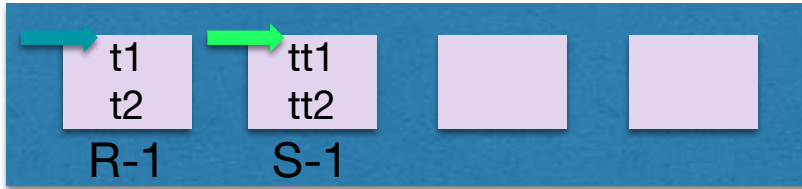
Nested Loop Join

DB

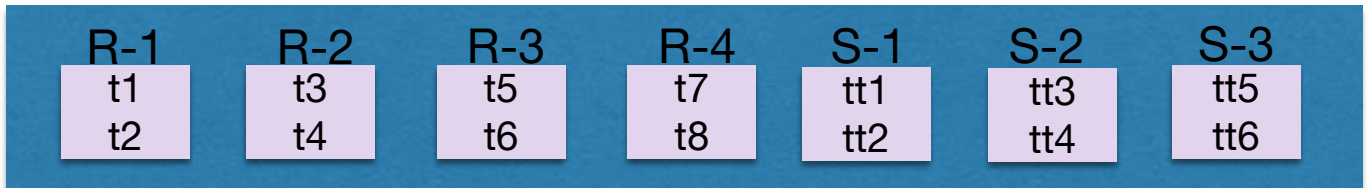
$R \bowtie_p S \dots \text{Join.open}()$

```
R.open()  
S.open()  
r := R.next()
```

Buffer



Disco



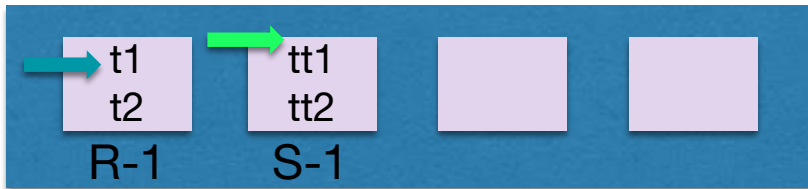
Nested Loop Join

DB

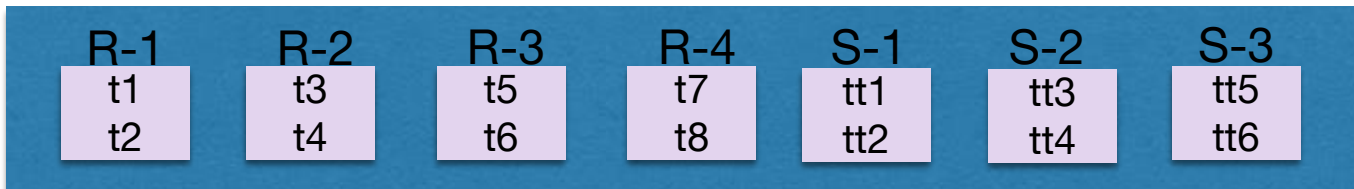
$R \bowtie_p S \dots \text{Join.open}()$

```
R.open()  
S.open()  
r := R.next()
```

Buffer



Disco

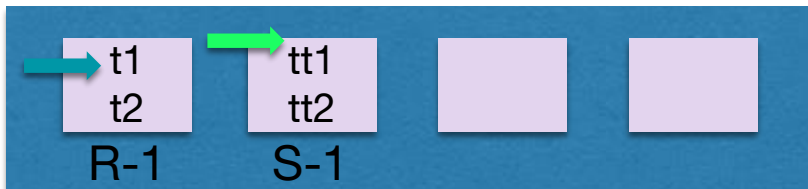


Nested Loop Join

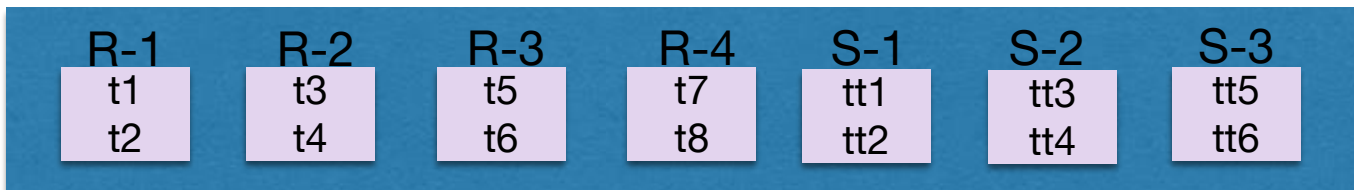
DB

```
t:= Join.next()  
while t != null do  
    output t  
    t:= Join.next()
```

Buffer



Disco



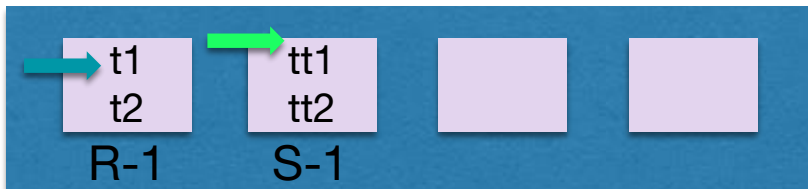
Nested Loop Join

DB

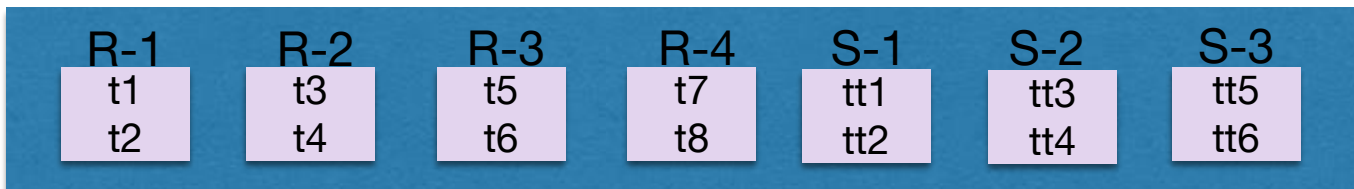
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

```
next()
while r != null do
    s := S.next()
    if s == null then
        S.close()
        r := R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
return null
```

Buffer



Disco



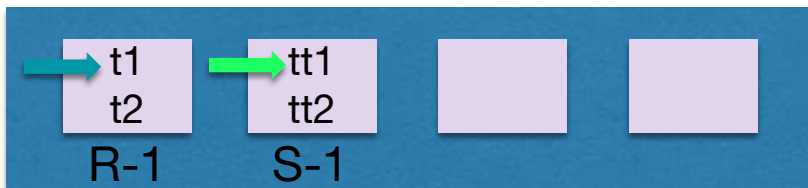
Nested Loop Join

DB

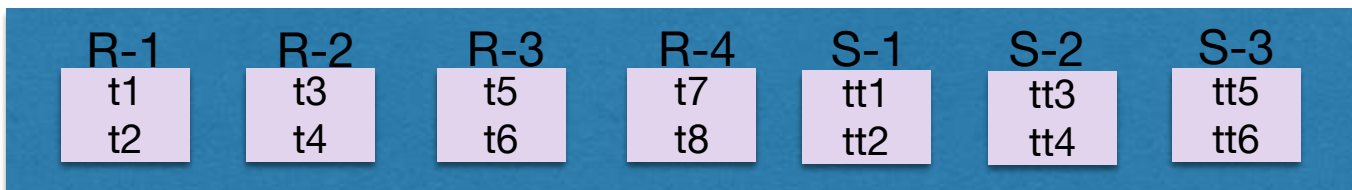
```
t:= Join.next()
while t != null do
    output t
    t:= Join.next()
```

```
next()
while r != null do
    s:= S.next()
    if s == null then
        S.close()
        r:= R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
return null
```

Buffer



Disco



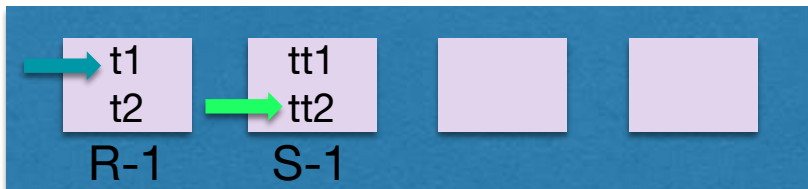
Nested Loop Join

DB

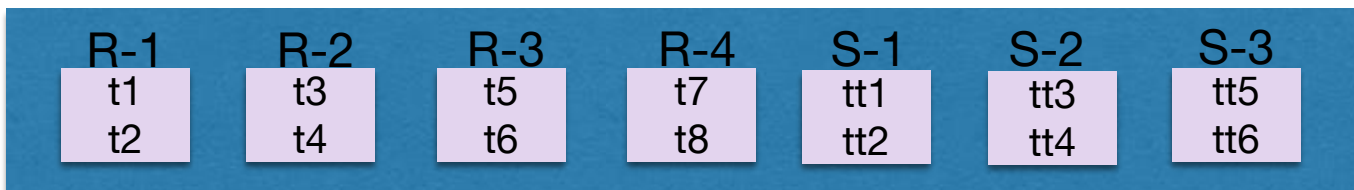
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

```
next()
while r != null do
    s := S.next()
    if s == null then
        S.close()
        r := R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
return null
```

Buffer



Disco



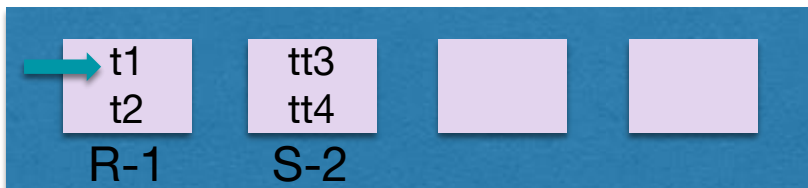
Nested Loop Join

DB

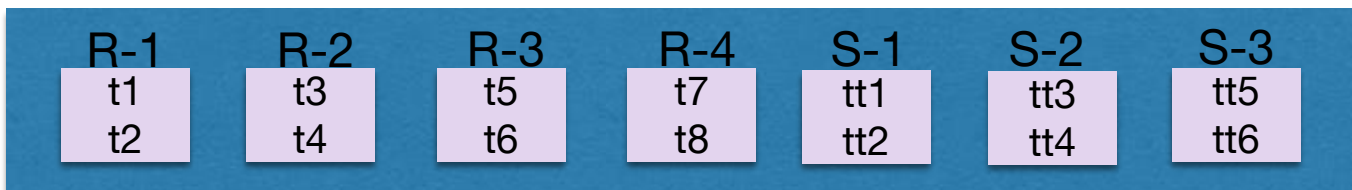
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

```
next()
while r != null do
    s := S.next()
    if s == null then
        S.close()
        r := R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
    return null
```

Buffer



Disco



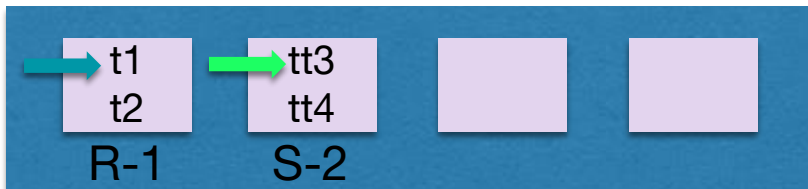
Nested Loop Join

DB

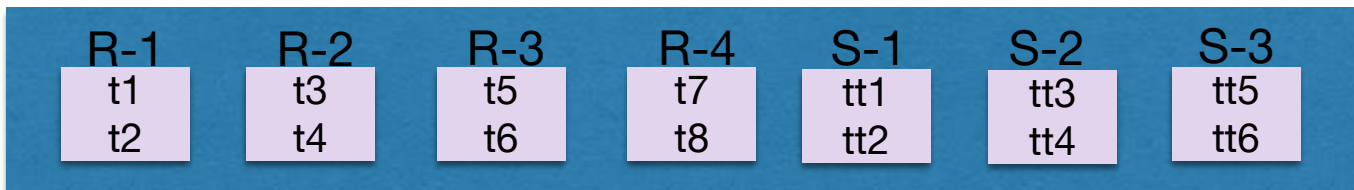
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

```
next()
while r != null do
    s := S.next()
    if s == null then
        S.close()
        r := R.next()
        S.open()
    else if r ⋈p s
        return (r, s)
return null
```

Buffer



Disco



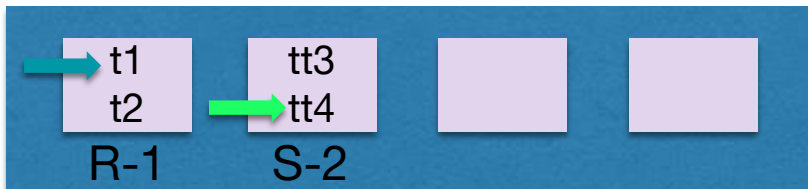
Nested Loop Join

DB

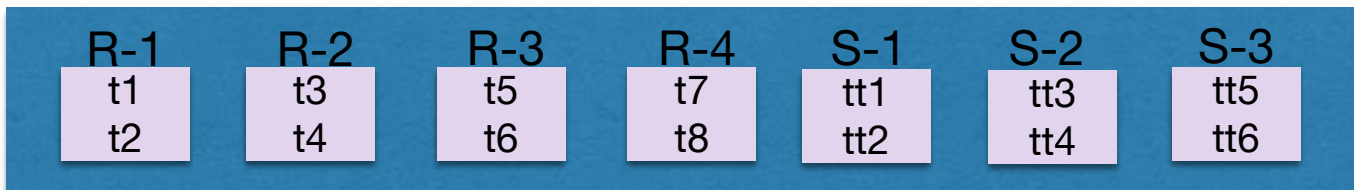
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

```
next()
while r != null do
    s := S.next()
    if s == null then
        S.close()
        r := R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
return null
```

Buffer



Disco



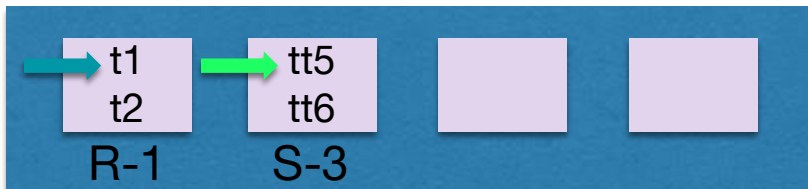
Nested Loop Join

DB

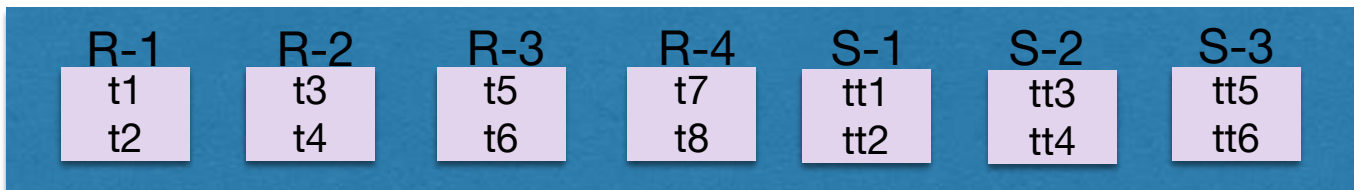
```
t:= Join.next()
while t != null do
    output t
    t:= Join.next()
```

```
next()
while r != null do
    s:= S.next()
    if s == null then
        S.close()
        r:= R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
    return null
```

Buffer



Disco



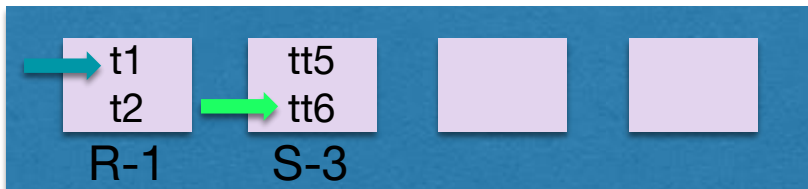
Nested Loop Join

DB

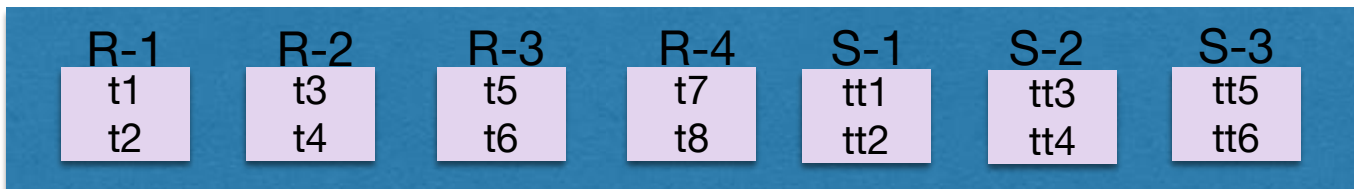
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

```
next()
while r != null do
    s := S.next()
    if s == null then
        S.close()
        r := R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
return null
```

Buffer



Disco



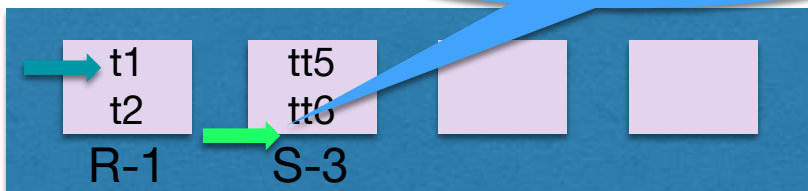
Nested Loop Join

DB

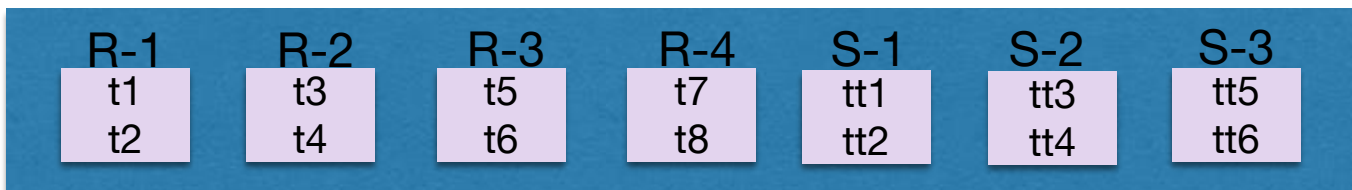
```
t := Join.next()
while t != null do
  output t
  t := Join.next()
```

```
next()
while r != null do
  s := S.next()
  if s == null then
    S.close()
    r := R.next()
    S.open()
  else if r  $\bowtie_p$  s
    return (r, s)
return null
```

Buffer



Disco



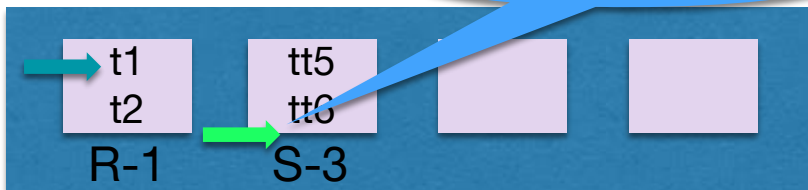
Nested Loop Join

DB

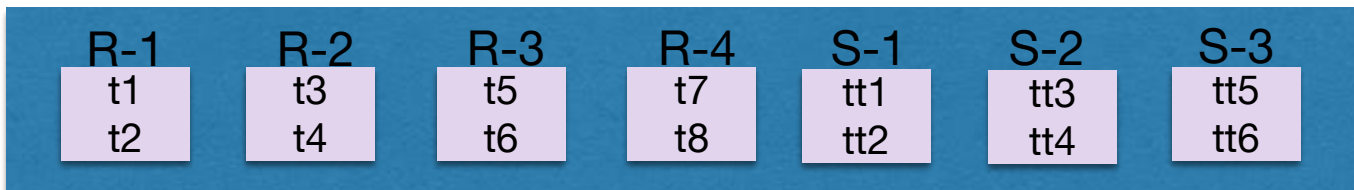
```
t := Join.next()
while t != null do
  output t
  t := Join.next()
```

```
next()
while r != null do
  s := S.next()
  if s == null then
    S.close()
    r := R.next()
    S.open()
  else if r  $\bowtie_p$  s
    return (r, s)
  return null
```

Buffer



Disco



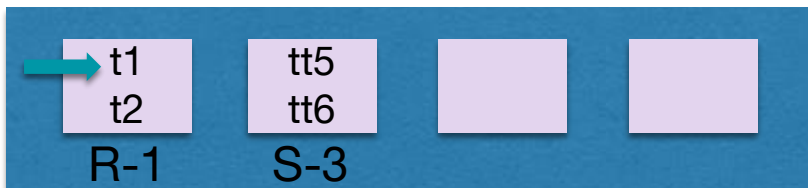
Nested Loop Join

DB

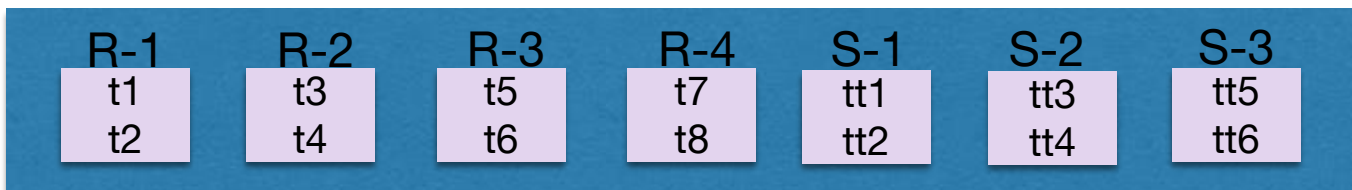
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

```
next()
while r != null do
    s := S.next()
    if s == null then
        S.close()
        r := R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
return null
```

Buffer



Disco



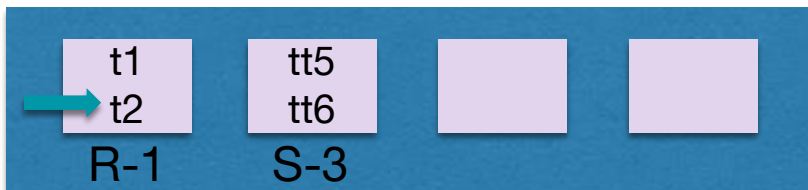
Nested Loop Join

DB

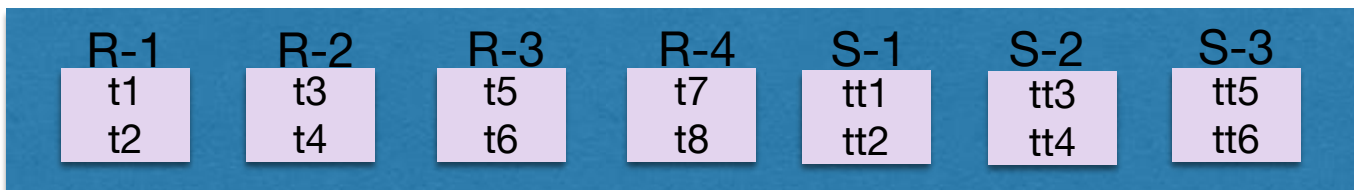
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

```
next()
while r != null do
    s := S.next()
    if s == null then
        S.close()
        r := R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
return null
```

Buffer



Disco



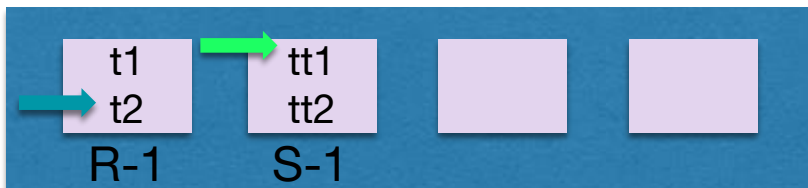
Nested Loop Join

DB

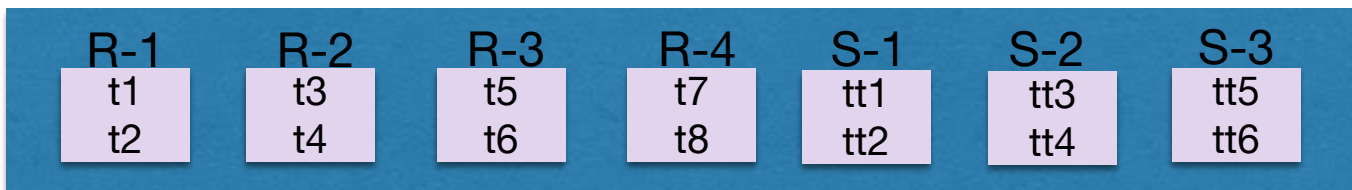
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

```
next()
while r != null do
    s := S.next()
    if s == null then
        S.close()
        r := R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
    return null
```

Buffer



Disco



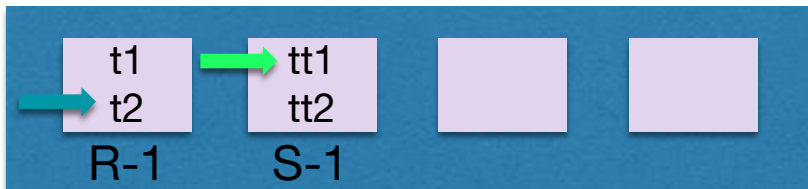
Nested Loop Join

DB

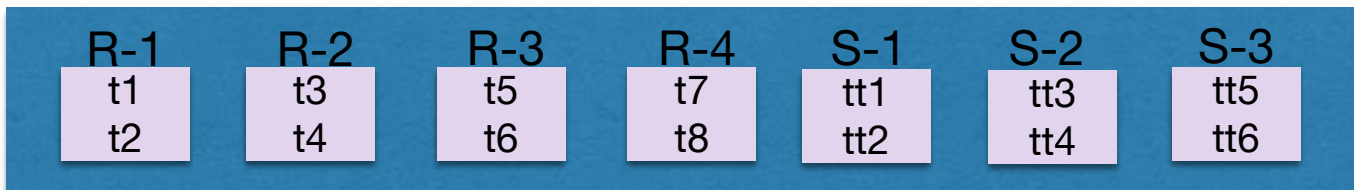
```
t := Join.next()
while t != null do
    output t
    t := Join.next()
```

```
next()
while r != null do
    s := S.next()
    if s == null then
        S.close()
        r := R.next()
        S.open()
    else if r  $\bowtie_p$  s
        return (r, s)
return null
```

Buffer



Disco



Nested Loop Join

Es una implementación directa basada en un loop

Para cada tupla de **R** debemos leer **S** entera, aparte de leer **R** entera una vez

Costo en I/O es:

$$\text{Costo}(\mathbf{R}) + \text{Tuplas}(\mathbf{R}) \cdot \text{Costo}(\mathbf{S})$$

Nested Loop Join

Si **R** y **S** son tablas de 16 MB, cada página es de 8 KB y las tuplas son de 300 bytes

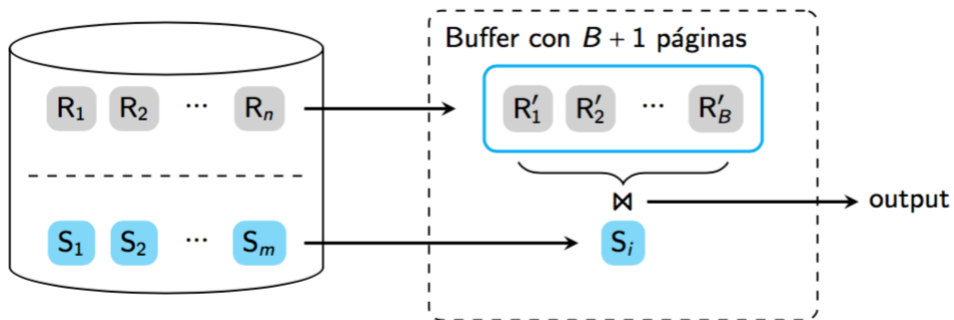
Cada relación tiene 2048 páginas y 55.000 tuplas aproximadamente

Costo de un I/O es 0.1 ms, entonces el join tarda:

3.1 horas

Block Nested Loop Join

Aprovechamos mejor el buffer



Block Nested Loop Join

Queremos hacer un join entre **R** y **S**, cuando se satisface un predicado **p**

```
open()
  R.open()
  fillBuffer()

close()
  R.close()
  S.close()

fillBuffer()
  Buff = empty
  r:= R.next()
  while r != null do
    Buff = Buff union r
    if Buff.isFull() then
      break
  r:= R.next()
  S.open()
  S.next()
```

Block Nested Loop Join

Queremos hacer un join entre **R** y **S**, cuando se satisface un predicado **p**

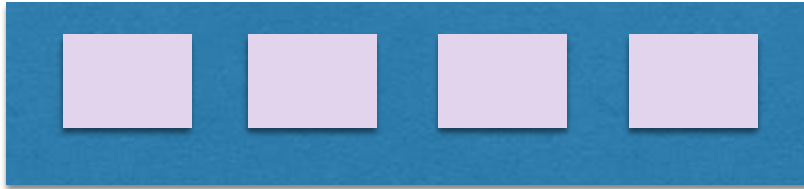
```
next()
  while Buff != empty do
    while s != null do
      r:= Buffer.next()
      if r == null then
        Buffer.reset()
        s:= S.next()
      else if (r,s) satisfacen p then
        return (r,s)
    fillBuffer()
  return null
```


Block Nested Loop Join

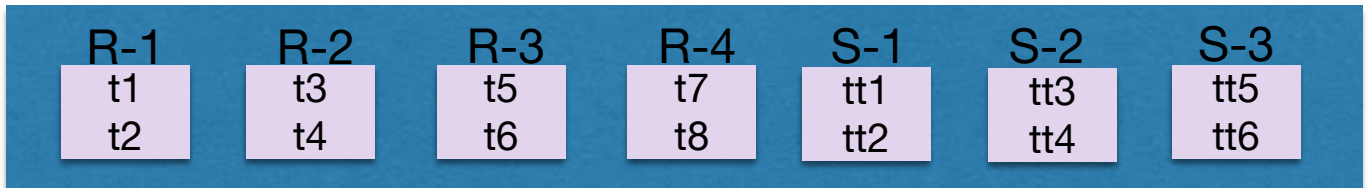
DB

$R \bowtie_p S$

Buffer



Disco

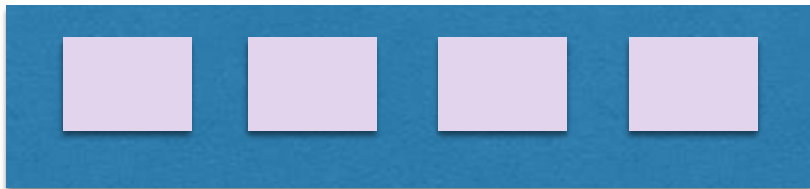


Block Nested Loop Join

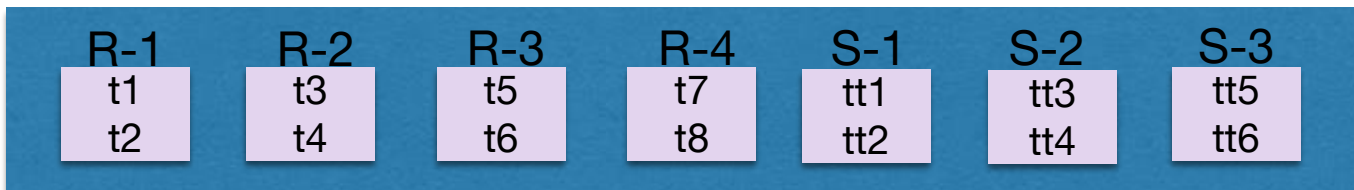
DB

$R \bowtie_p S.open()$

Buffer



Disco

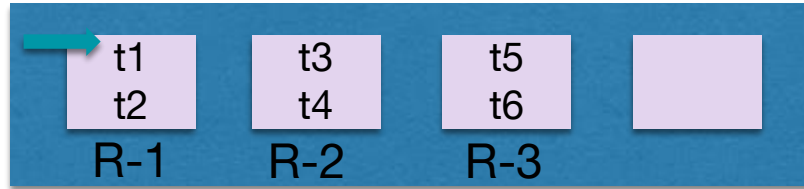


Block Nested Loop Join

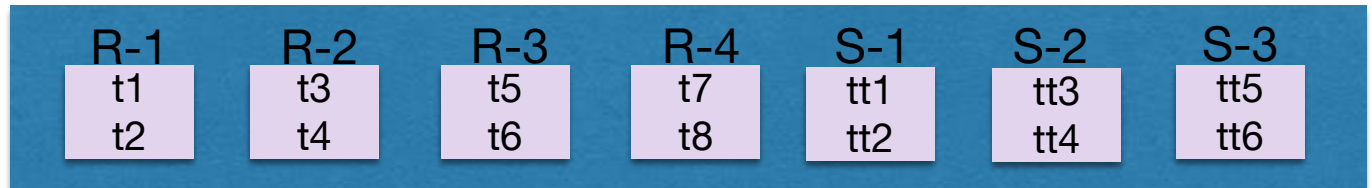
DB

$R \bowtie_p S.open()$

Buffer



Disco

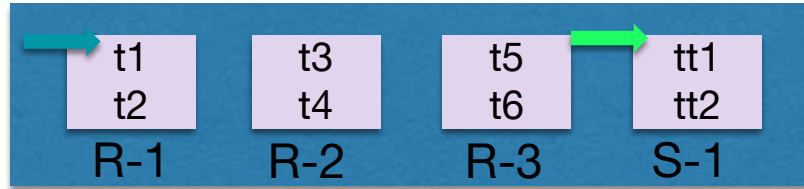


Block Nested Loop Join

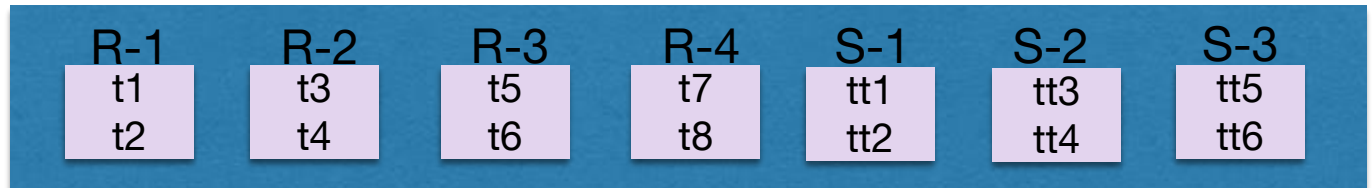
DB

$R \bowtie_p S.open()$

Buffer



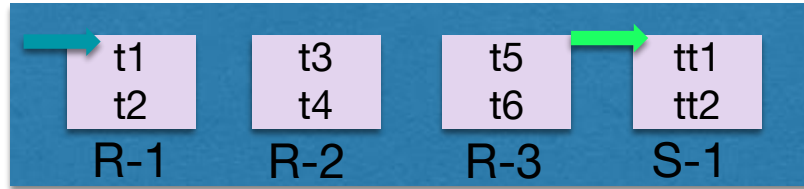
Disco



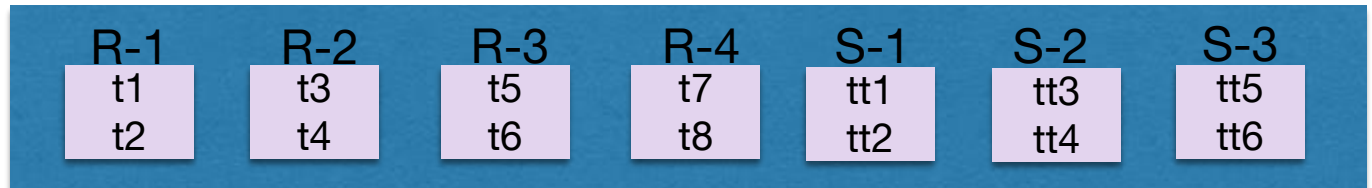
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



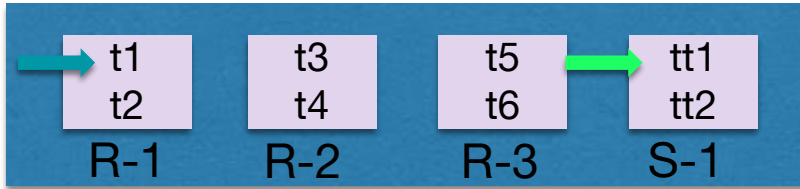
Disco



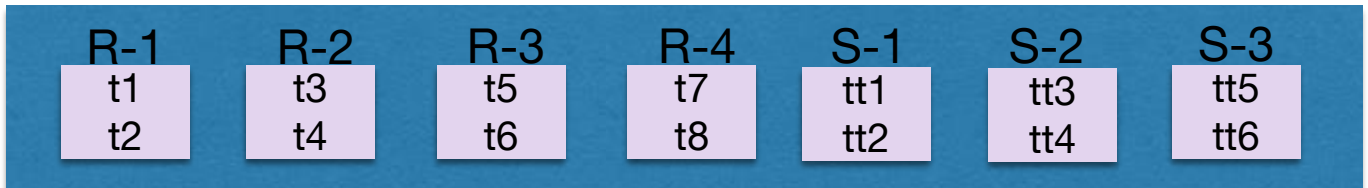
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



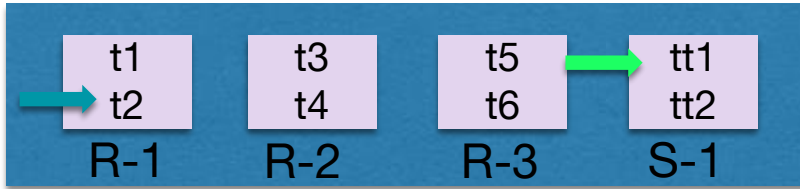
Disco



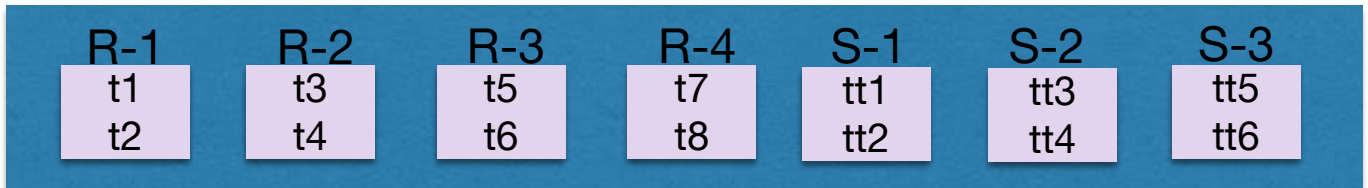
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



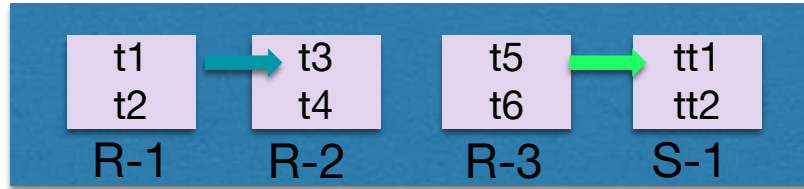
Disco



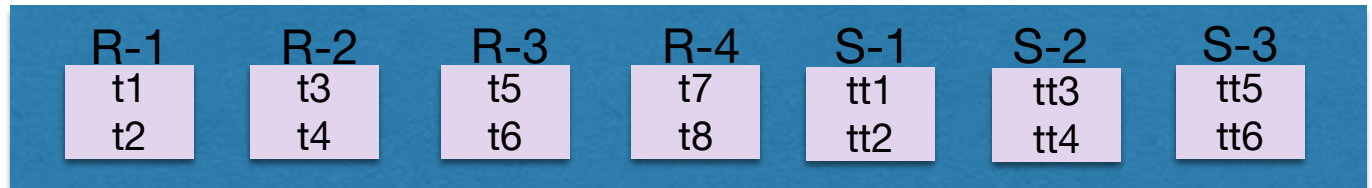
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



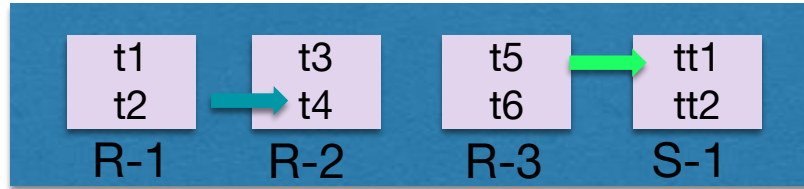
Disco



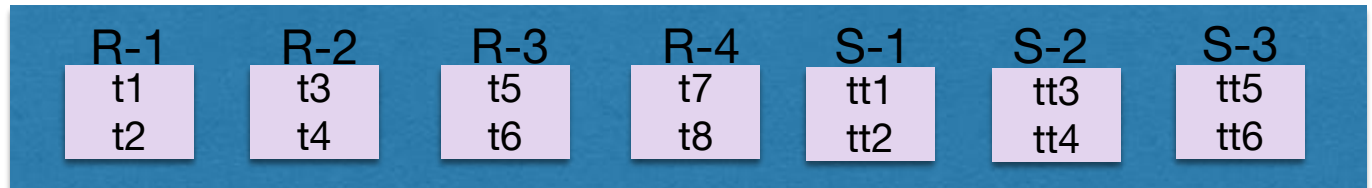
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



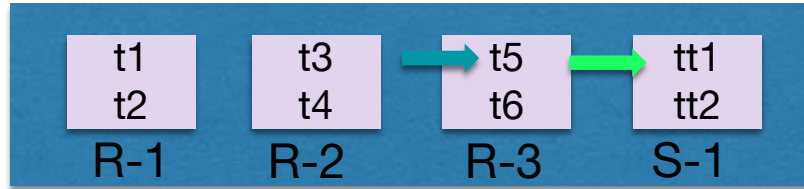
Disco



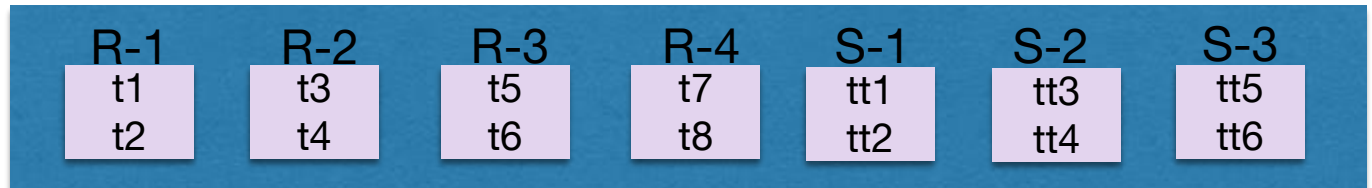
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



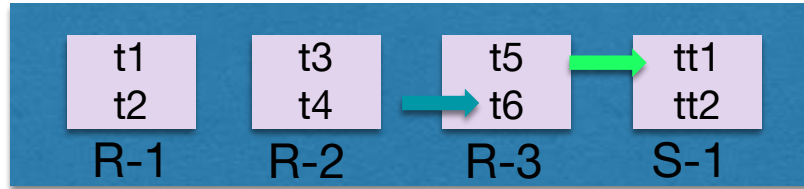
Disco



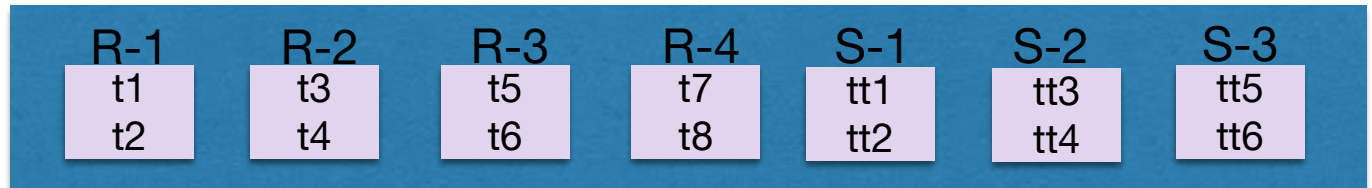
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



Disco



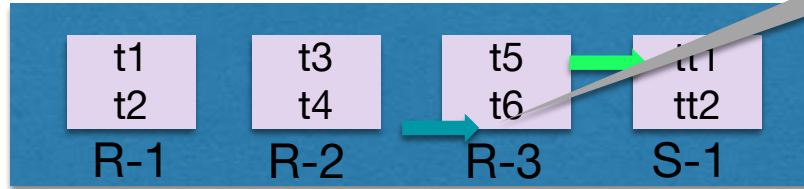
Block Nested Loop Join

DB

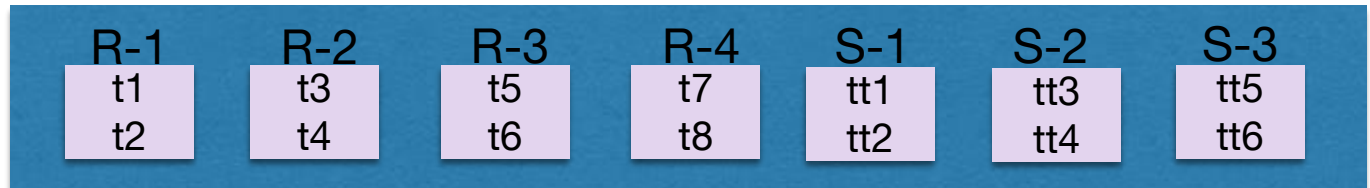
while ($R \bowtie_p S.next()$)

End of Buffer de R

Buffer



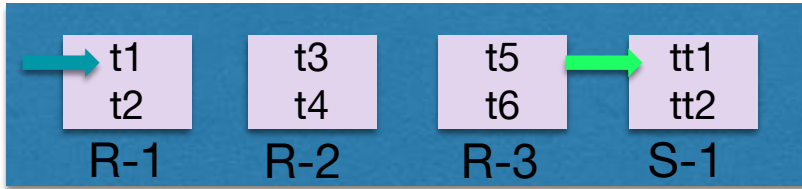
Disco



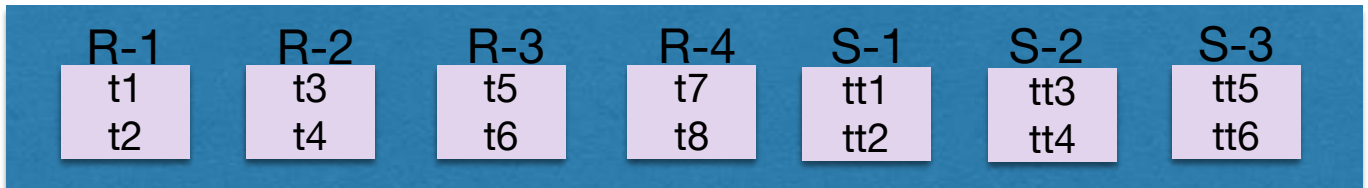
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



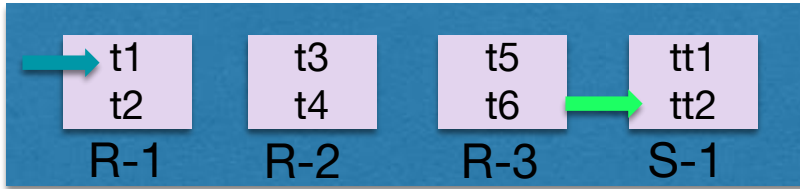
Disco



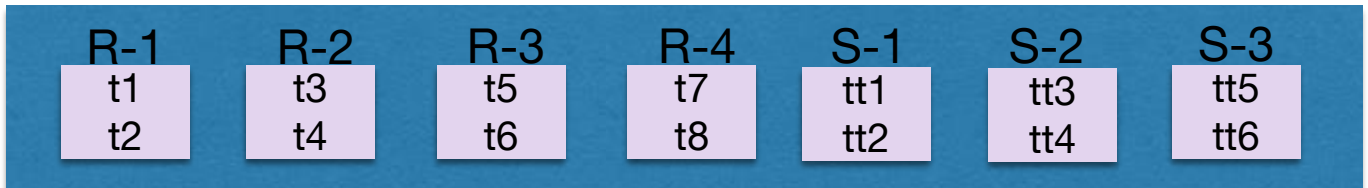
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



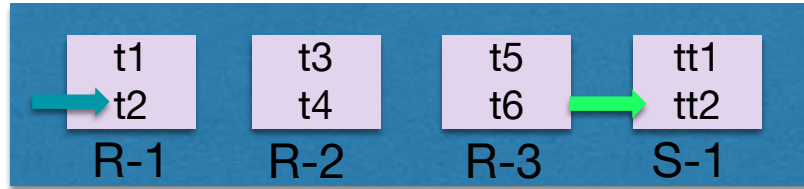
Disco



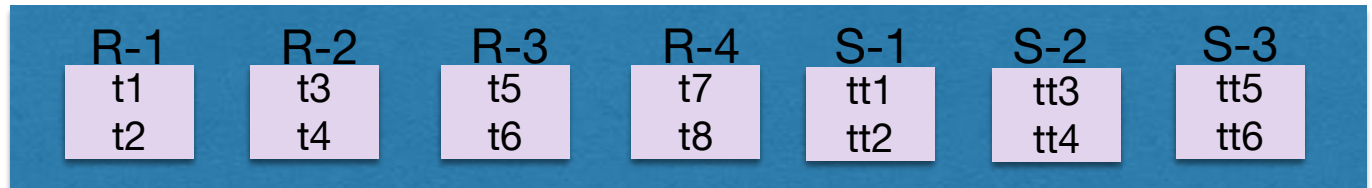
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



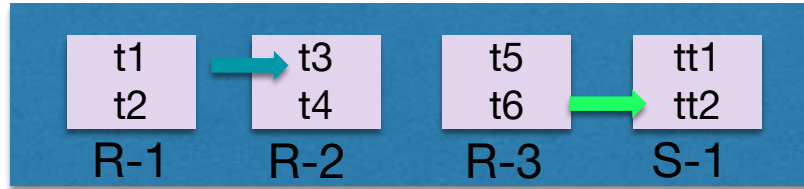
Disco



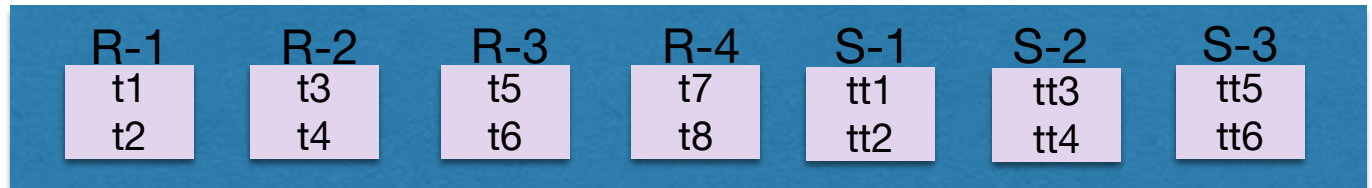
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



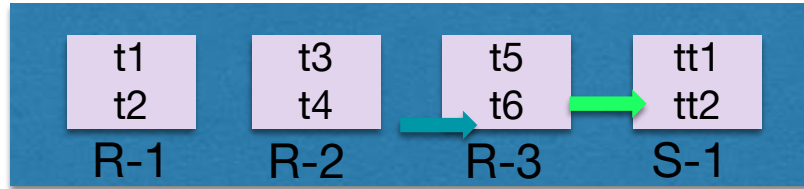
Disco



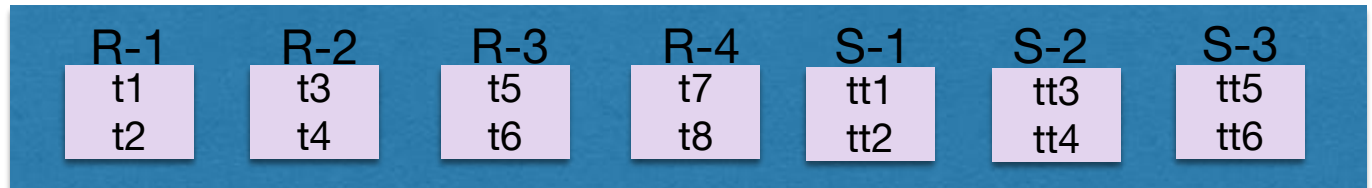
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



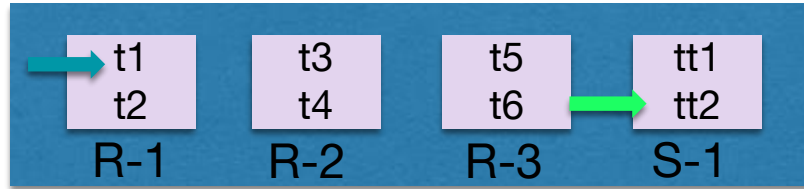
Disco



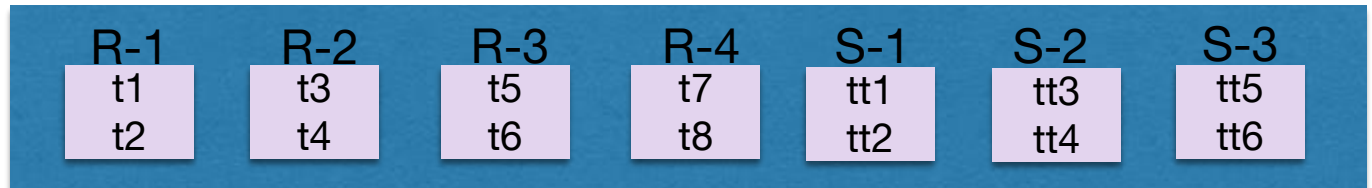
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



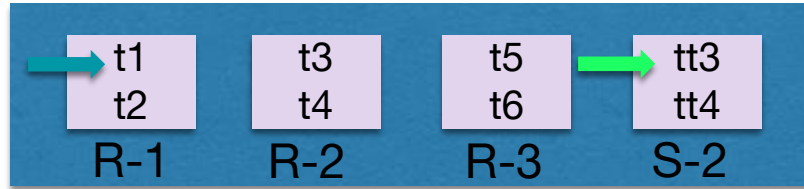
Disco



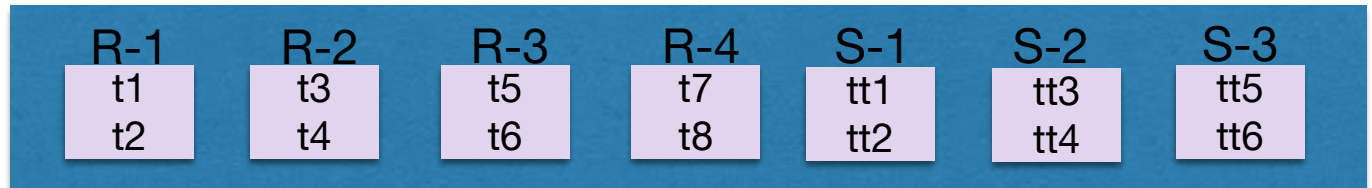
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



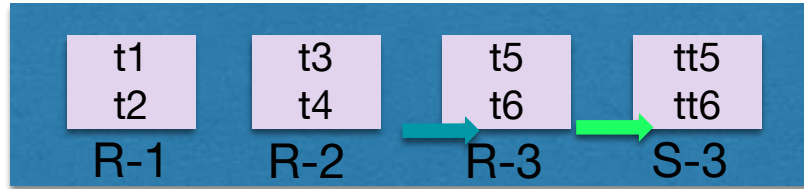
Disco



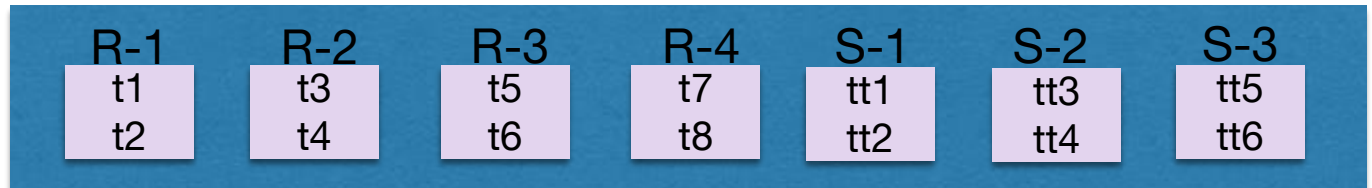
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



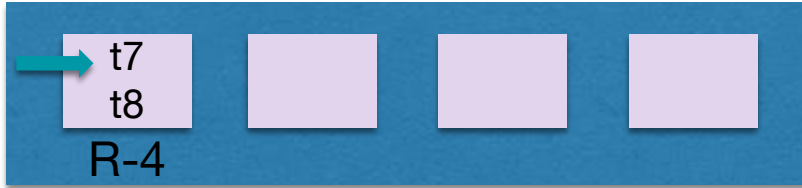
Disco



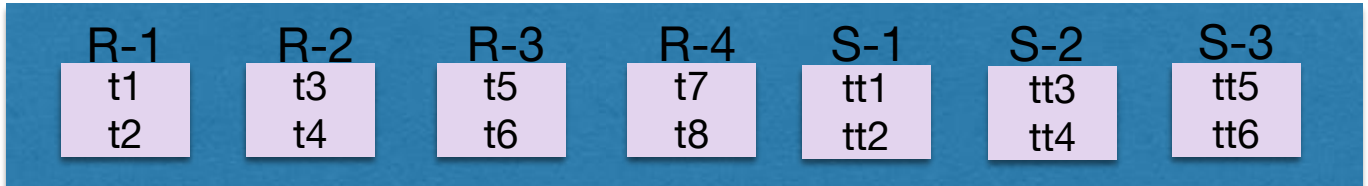
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



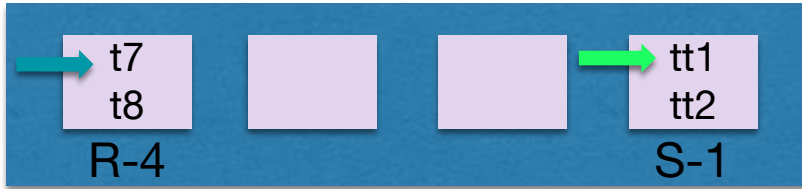
Disco



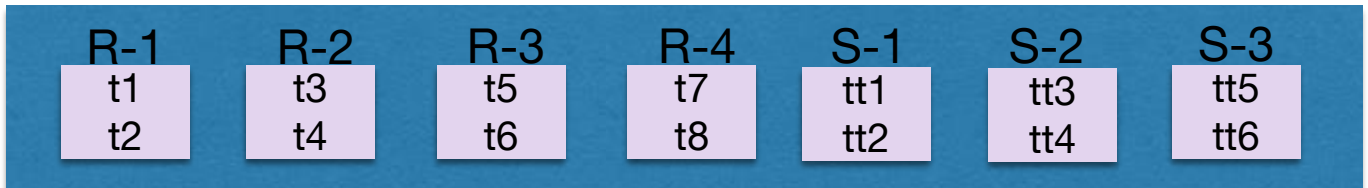
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



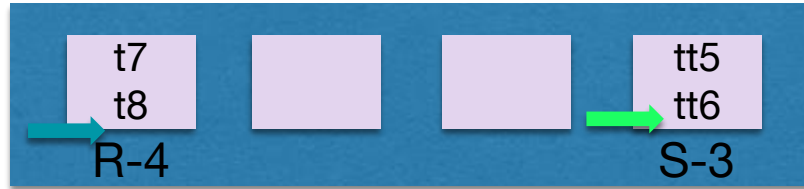
Disco



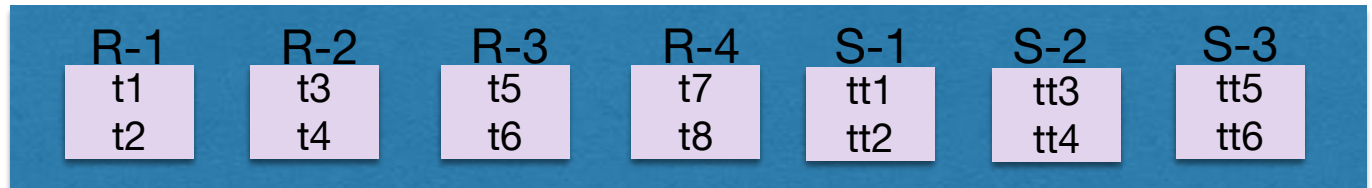
Block Nested Loop Join

DB while ($R \bowtie_p S.next()$)

Buffer



Disco



Block Nested Loop Join

Ahora cargamos muchas páginas de **R** a buffer

Por cada vez que llenamos el buffer recorremos a **S** entera una vez

Costo en I/O es:

$$\text{Costo}(\mathbf{R}) + (\text{Páginas}(\mathbf{R})/\text{Buffer}) \cdot \text{Costo}(\mathbf{S})$$

Block Nested Loop Join

Si **R** y **S** son tablas de 16 MB, cada página es de 8 KB con un **buffer** de 1 MB

Cada relación tiene 2048 páginas y en **buffer** caben 128 páginas

Costo de un I/O es 0.1 ms, entonces el join tarda:

3.4 segundos

Block Nested Loop Join

Sin embargo existen algoritmos muchos más eficientes

Estos algoritmos se basan en Hashing o en Sorting

Además hacen usos de índices, como por ejemplo el B+ Tree

Sorting

Los algoritmos de sorting son conocidos en programación

¿Por qué estudiarlos otra vez?

Sorting

Necesitamos ordenar tuplas que exceden por mucho el tamaño de la memoria RAM

External Merge Sort

En los DBMS, se utiliza el algoritmo External Merge Sort

Hablaremos de **Run** como una secuencia de páginas que contiene un conjunto ordenado de tuplas

Algoritmo funciona por **fases**

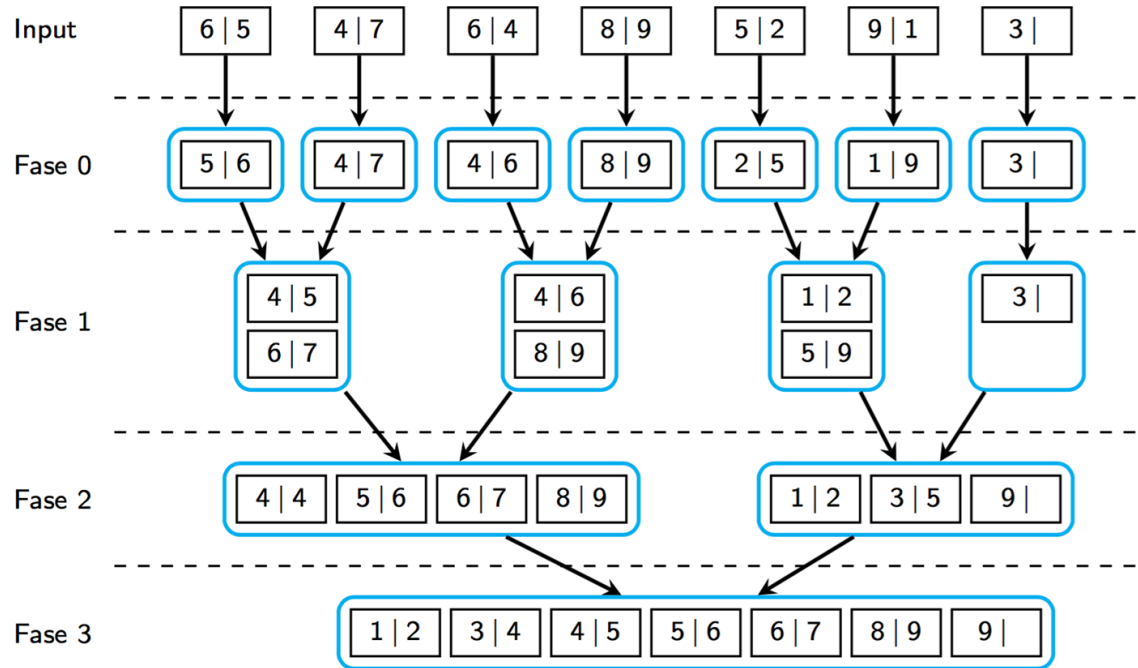
External Merge Sort

Fase 0: creamos los runs iniciales

Fase i:

- Traemos los runs a memoria
- Hacemos el merge de cada par de runs
- Almacenamos el nuevo run a disco (i.e. materializamos resultados intermedios)

External Merge Sort



Para más detalles tomar IIC3413 -
Implementación de sistemas de
Bases de Datos