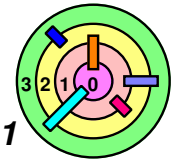
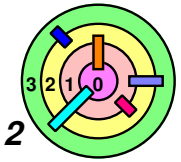
# 6.3 Directories and Naming

- Directories
- Name-Space Management



# Desired Properties of Directories

- No restrictions on names
- Fast
- Space-efficient



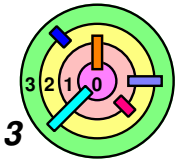
# S5FS Directories

| Component Name | Inode Number |
|---|---|

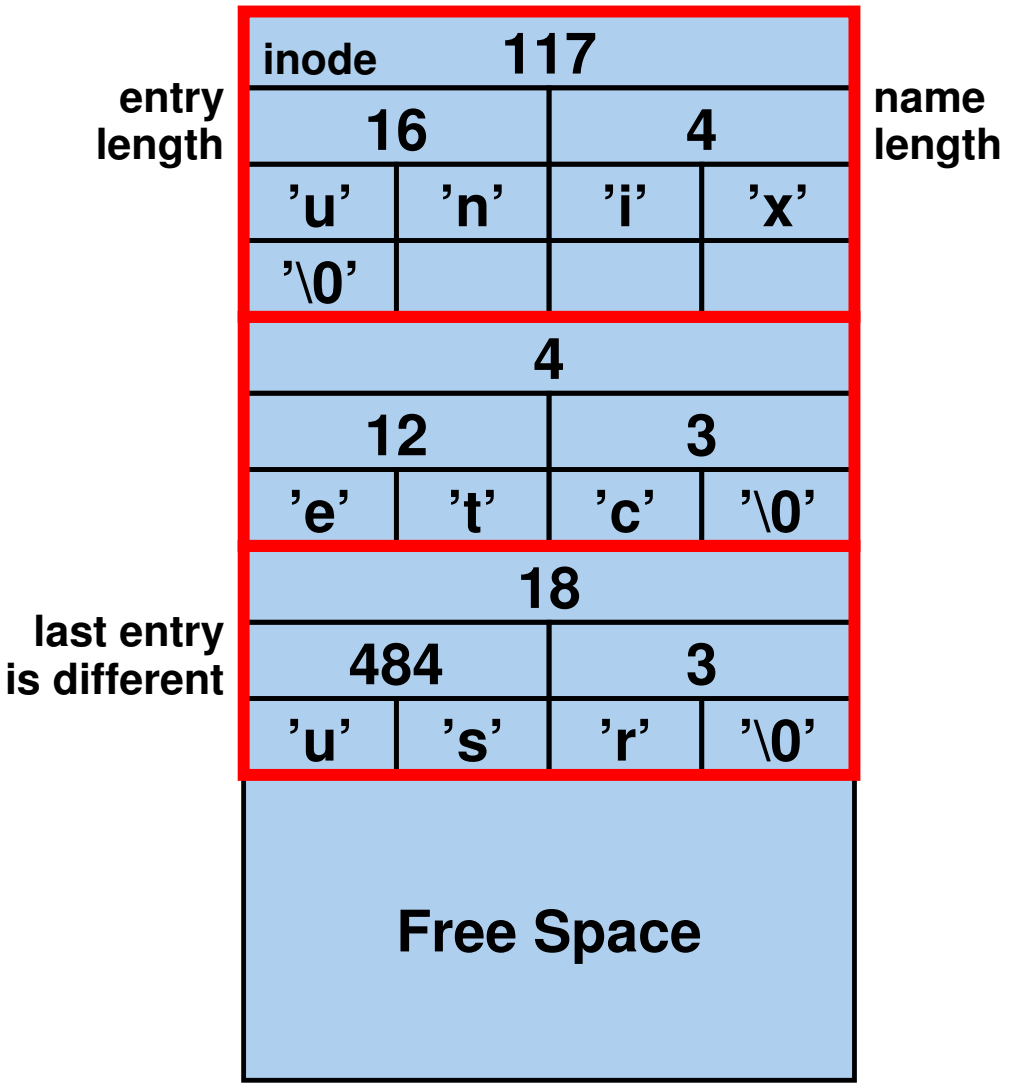
directory entry

| | |
|---|---|
| . | 1 |
| .. | 1 |
| unix | 117 |
| etc | 4 |
| home | 18 |
| pro | 36 |
| dev | 93 |

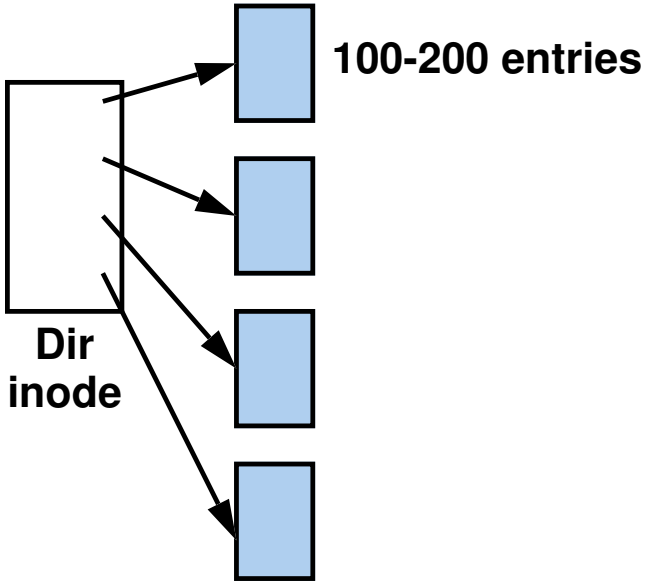
- each entry is 32 bytes long in S5FS (see "`s5fs.h`" in `weenix`)
- this is what get stored inside the "data blocks" of a directory
  - i.e., a directory is implemented as an inode and the disk map inside the inode points directly or indirectly to its "data blocks"



# FFS Directory Format

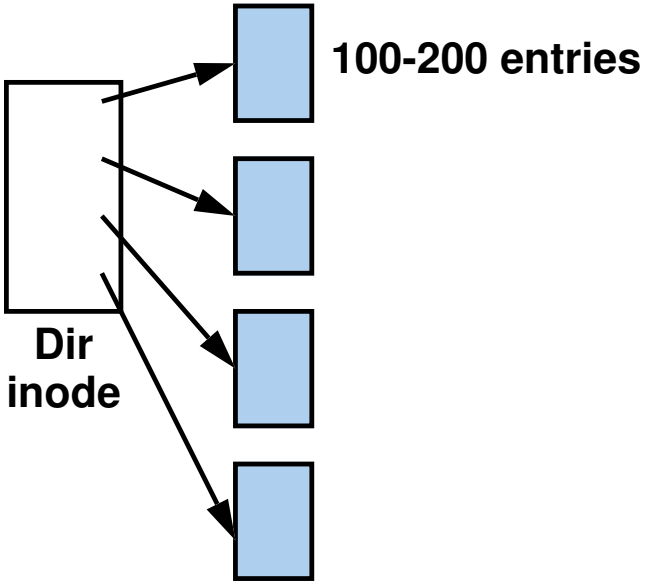


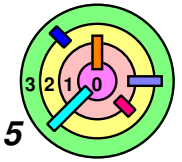

- unsorted entries



# Look Up Filename In A Directory

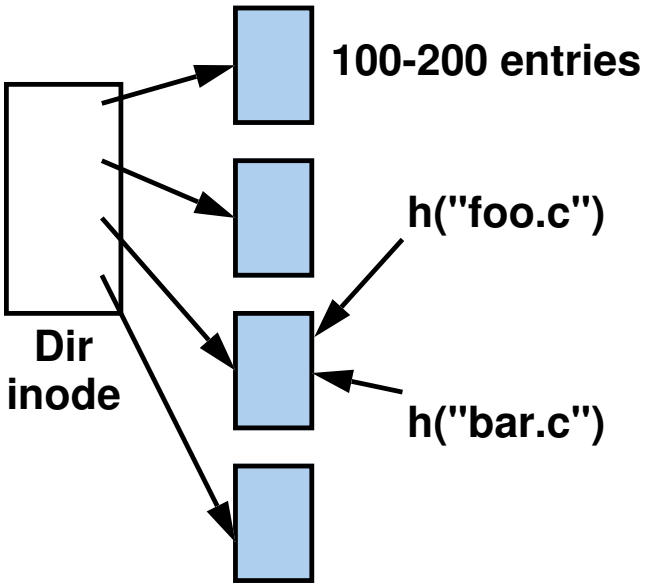
- How to look for a file named "foo.c"?
  - *O(n)* is no good
    - linear search
  - *O(log n)* is desirable
    - B+ tree
  - *O(1)* is great
    - hash table

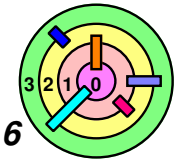


# Hash Table

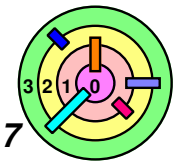
- Hash file names to disk blocks
  - don't treat the directory contents as a sequential file
  - treat it as an array of hash buckets
  - h(filename) tells you which bucket (i.e., block) the file information is in
    - one disk read
- The usual problem with hash tables
  - collisions



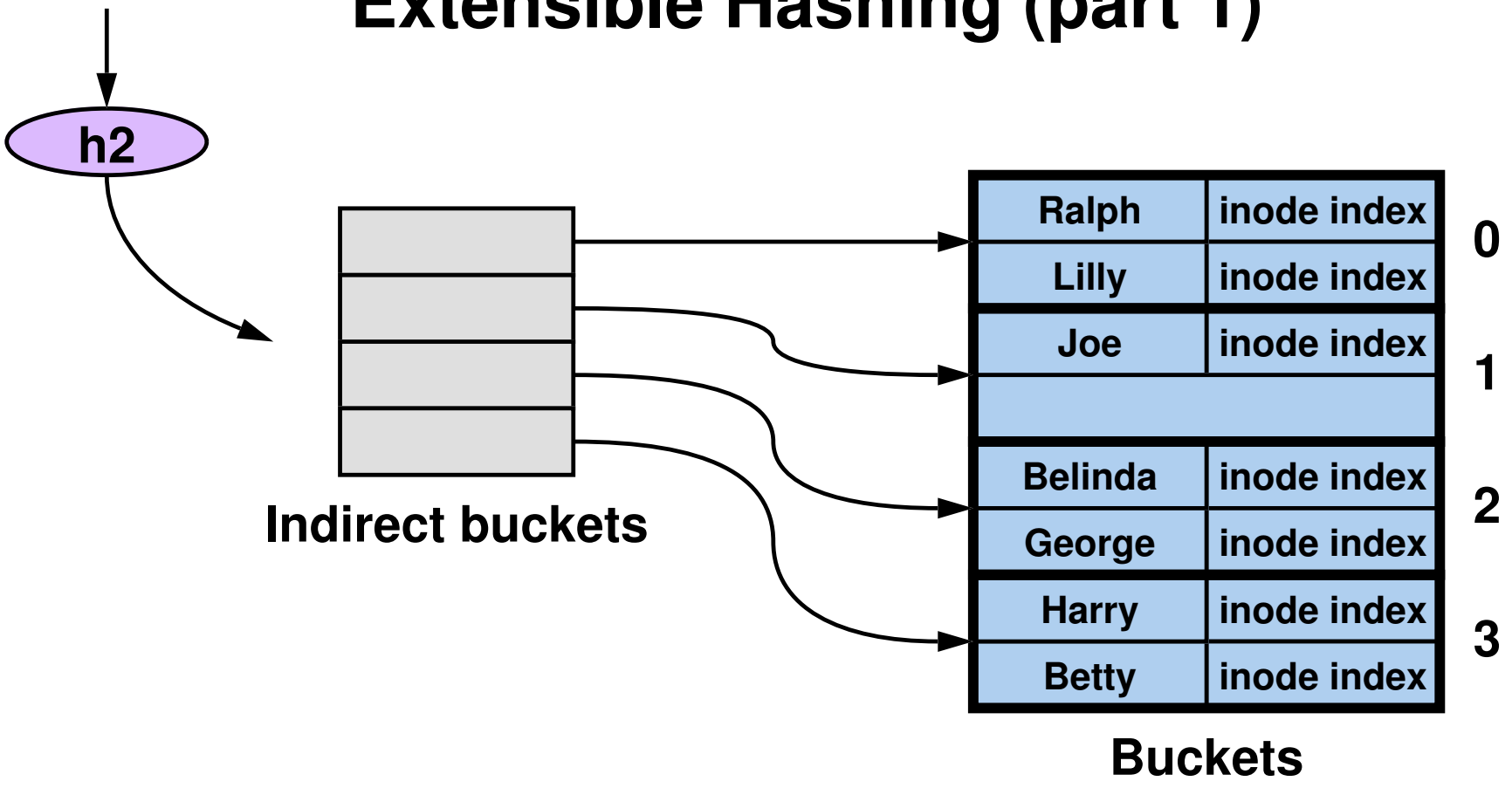



# Extensible Hashing

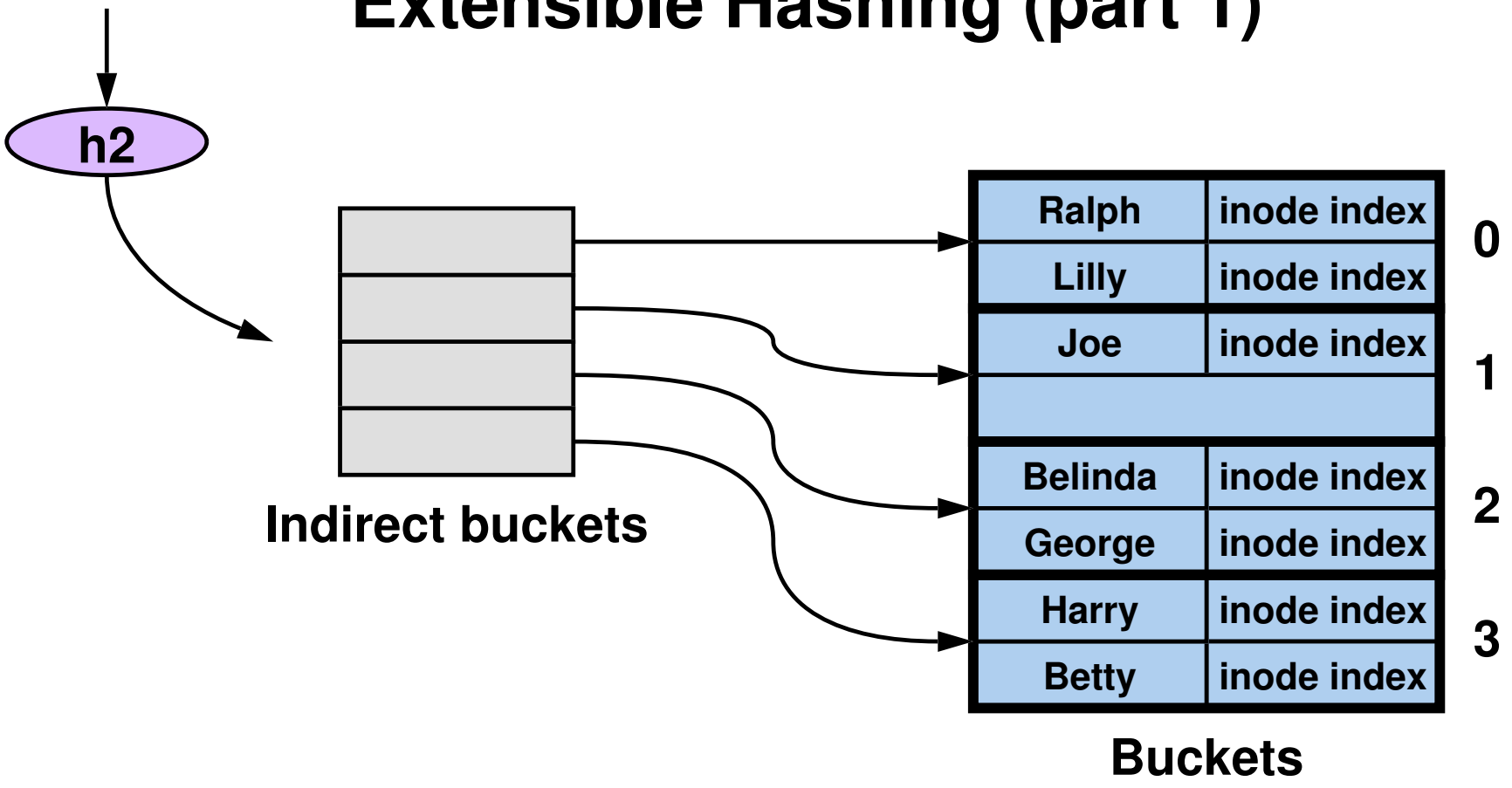
- Uses a sequence of hash functions, $h_0$, $h_1$, $h_2$, ...
  - where $h_i$ hashes names to $2^i$ buckets
  - for any name $x$, the low-order $i$ bits of $h_i(x)$ are the same in $h_{i+1}(x)$
    - $h_{i+1}$ is an *extension* on $h_i$



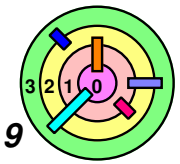
# Extensible Hashing (part 1)



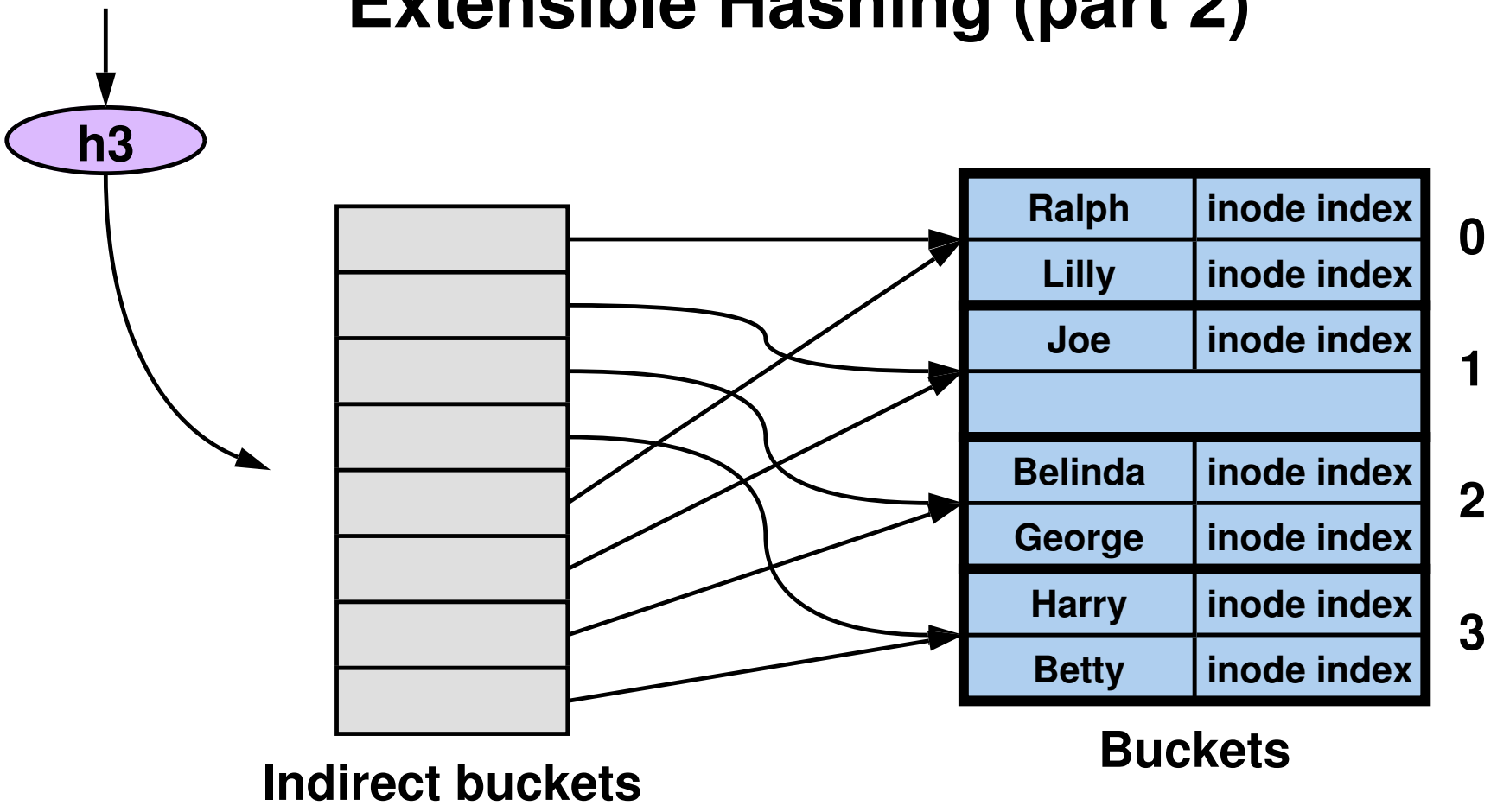
# Extensible Hashing (part 1)



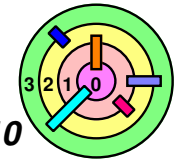

- insert(Fritz)
  - h2(Fritz) = 2
    - but bucket 2 is full



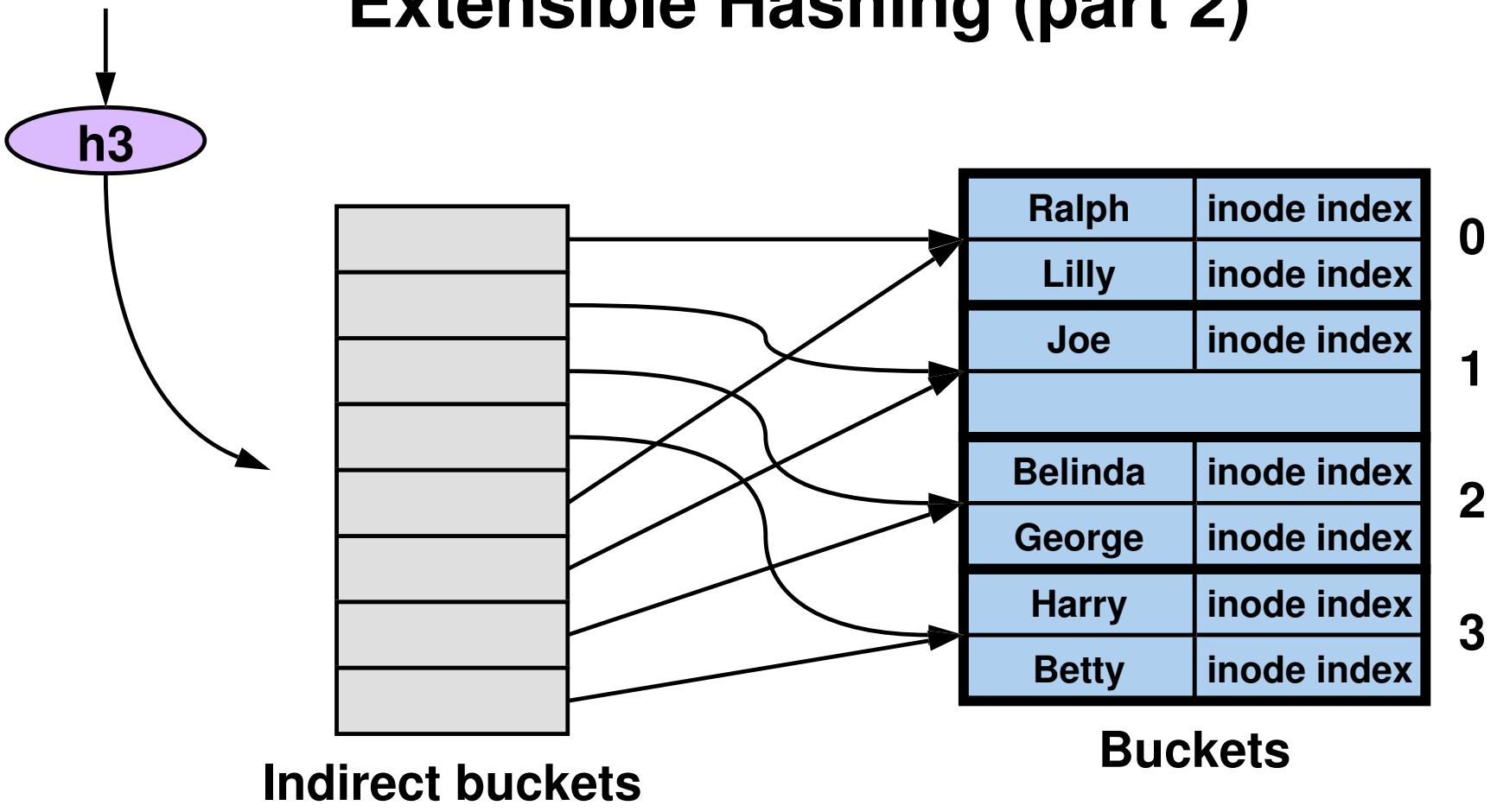
# Extensible Hashing (part 2)



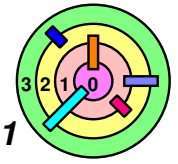

- First you double the number of indirect buckets
  - since there are 8 buckets, you need $h_3$
  - then you rehash all the entries in bucket 2 using $h_3$



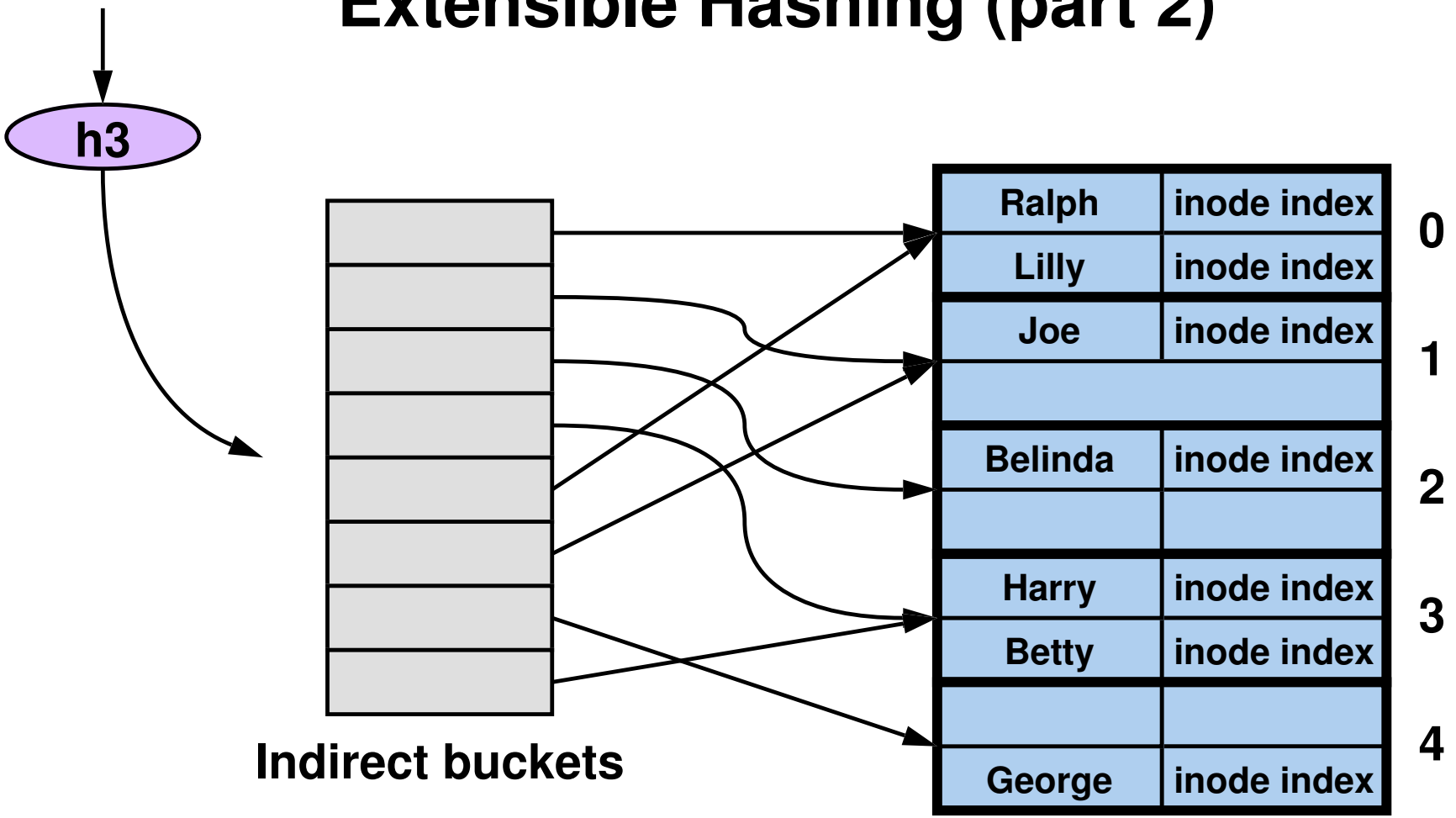
# Extensible Hashing (part 2)



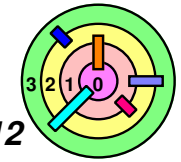

- h2(Fritz) = 2
  - rehash all items in bucket 2 with h3
    - on the average half of them should go to bucket 2 and the other half should go to bucket 6
    - h3(Belonda) = 2, h3(George) = 6



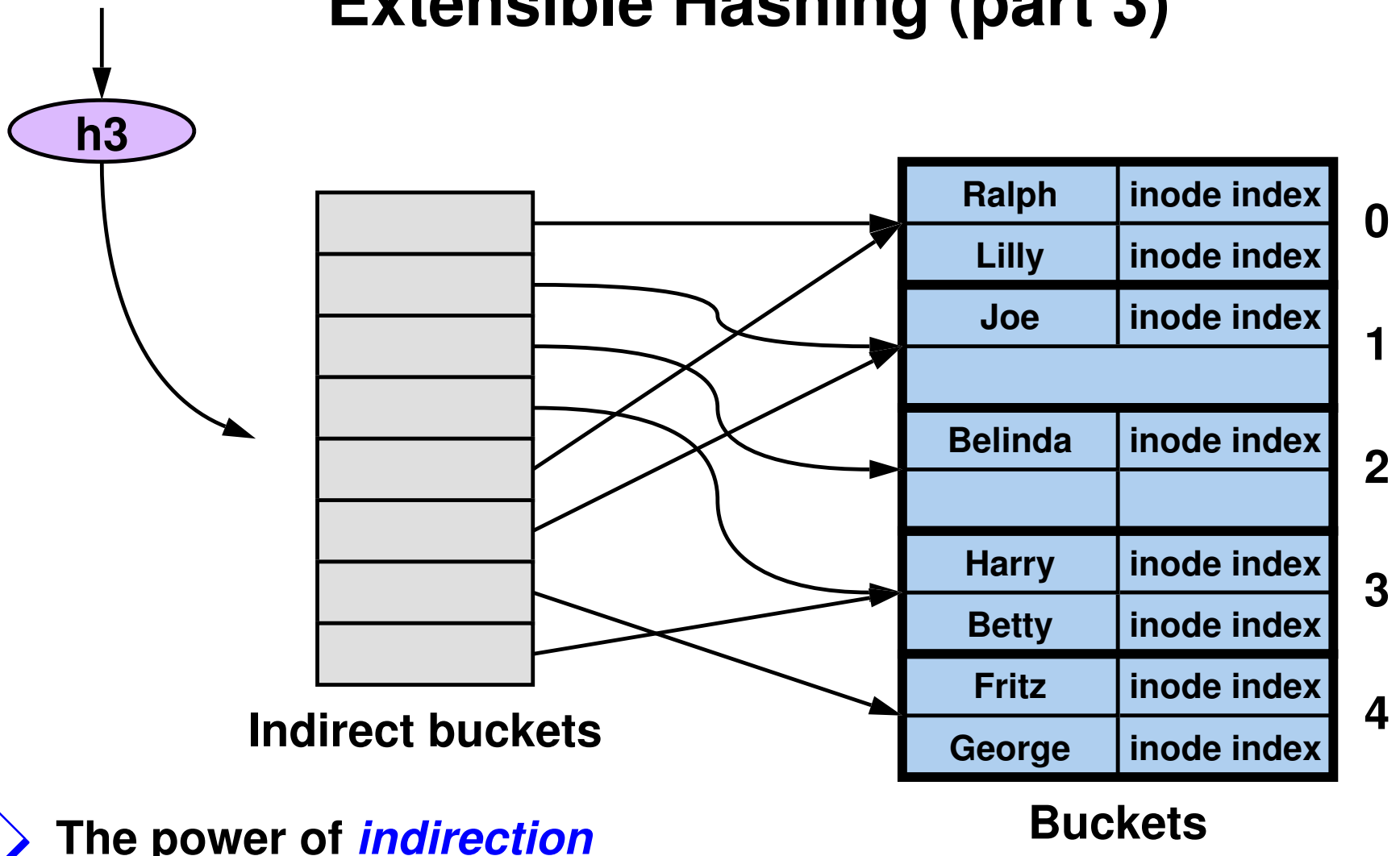
# Extensible Hashing (part 2)




- h2(Fritz) = 2
  - let's say h3(Fritz) = 6



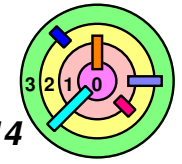
# Extensible Hashing (part 3)




- The power of *indirection*
  - without the indirect buckets, it will be expensive

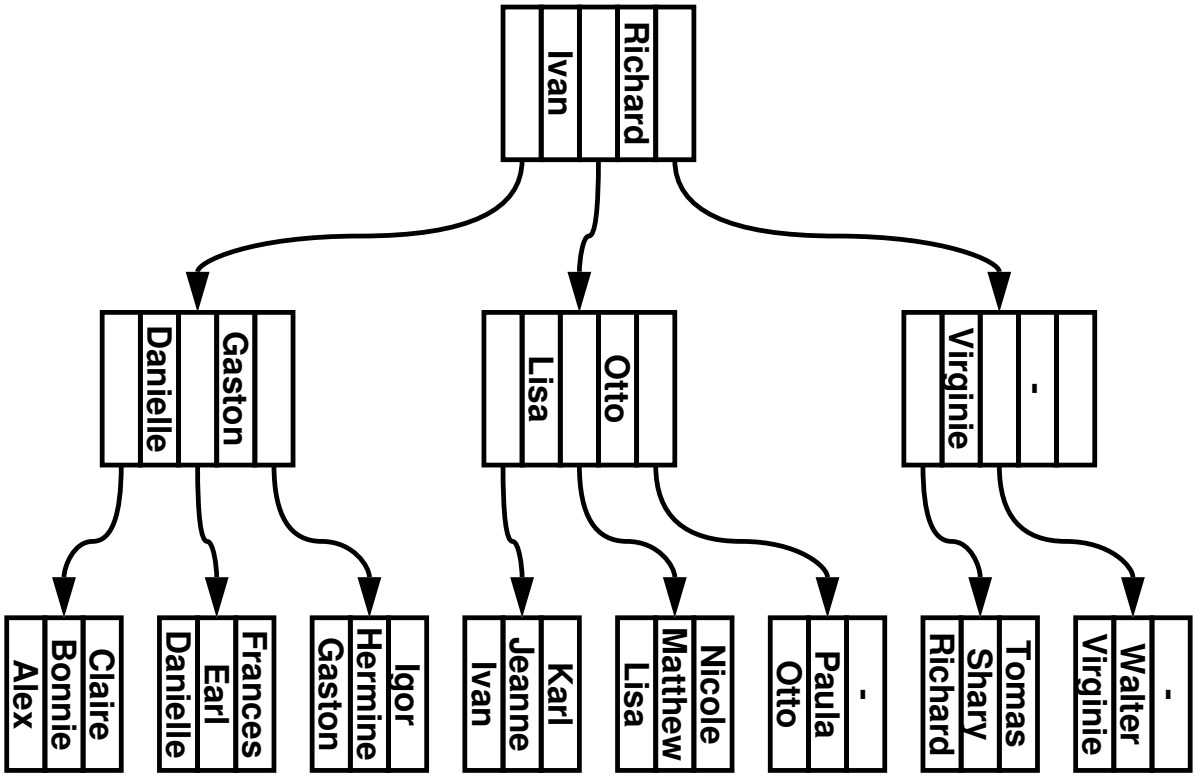
# B Trees

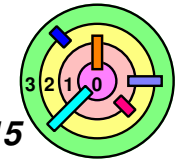
- A *B tree* of order *m* has the following properties:
  1) every node has ≤ *m* children
  2) every node (except root & leaves) has ≥ *ceil(m/2)* children
  3) the root has at least 2 children (unless it is also a leaf)
  4) all leaves appear at the *same level* and carry no keys
     - usually omitted from the drawings
  5) a non-leaf node with *k* children contains *k-1* keys
  - guarantee that each node of size *m* is at least 50% full
- Each *node* in a *B tree* corresponds to one *disk block*
  - *B+ tree:*
    - internal nodes contain no data, just keys
    - leaf nodes are linked to ease sorted sequential traversal
  - there are a lot of B tree variations in various application areas
- We will illustrate the basic idea with an example
  - actual B+ tree algorithm is more complicated than depicted



# B+ Trees (part 1)

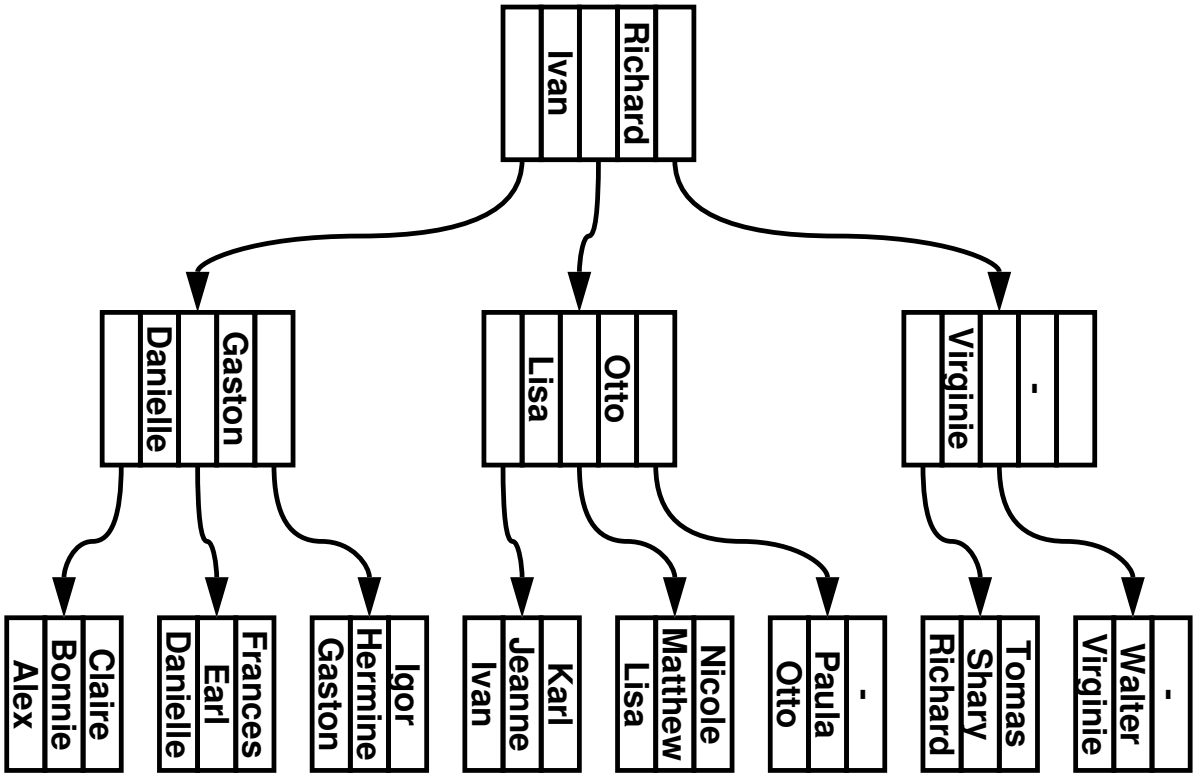
- Ex: a *B+ tree* of order 3
  - every internal node has either 2 or 3 children
    - if a node has > 3 children, it needs to split into two nodes
    - if a node has < 2 children, it needs to merge with its neighbor

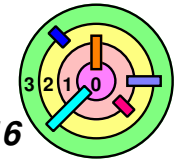


# B+ Trees (part 1)

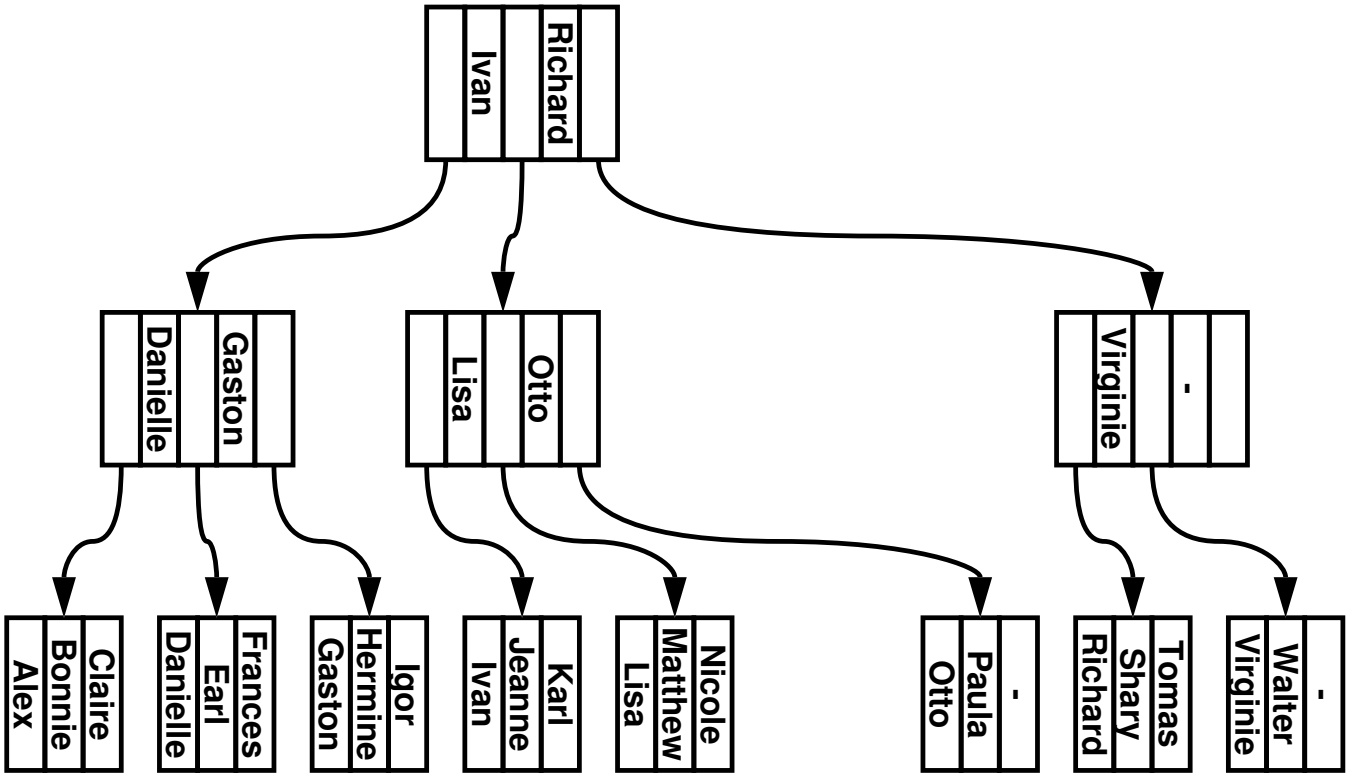
***Insertion:*** **e.g., "Lucy"**



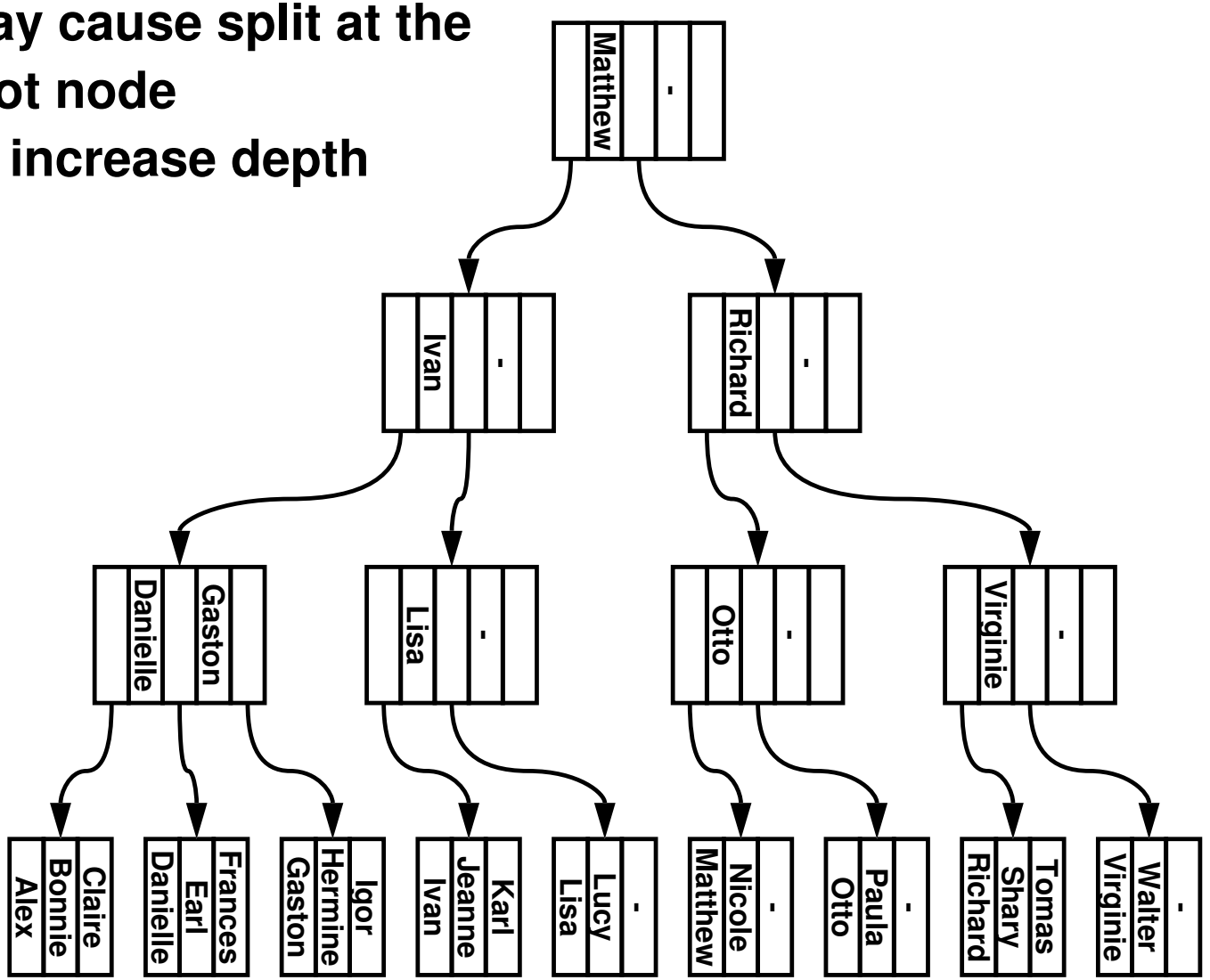
# B+ Trees (part 1)

***Insertion:*** **e.g., "Lucy"**



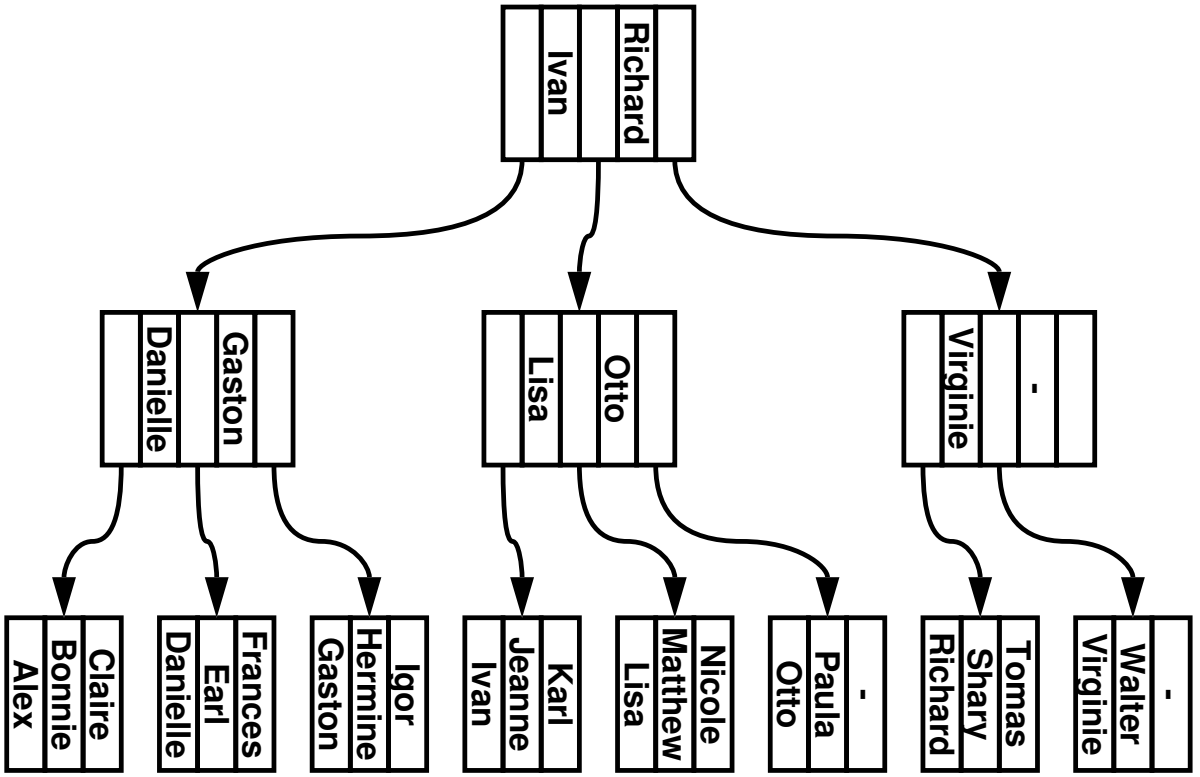
# B+ Trees (part 2)

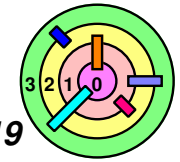
- ***Insertion:*** **e.g., "Lucy"**
  - **may cause split at the root node**
    - **increase depth**



# B+ Trees (part 2)

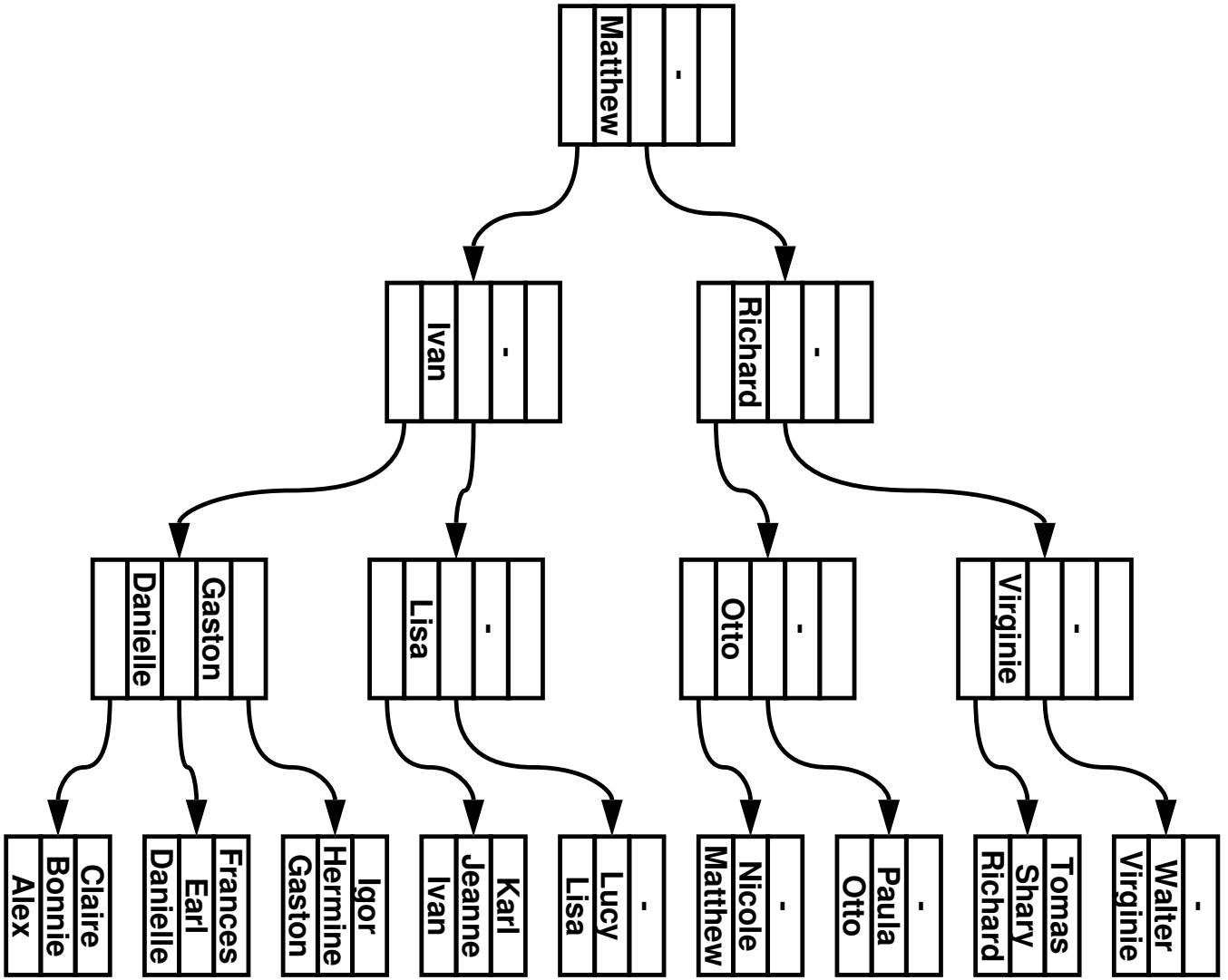
- ***Insertion:*** **e.g., "Lucy"**
  - **there is another way**
    - **"rotate" Nicole to the right (since cannot "rotate" Lisa to the left)**



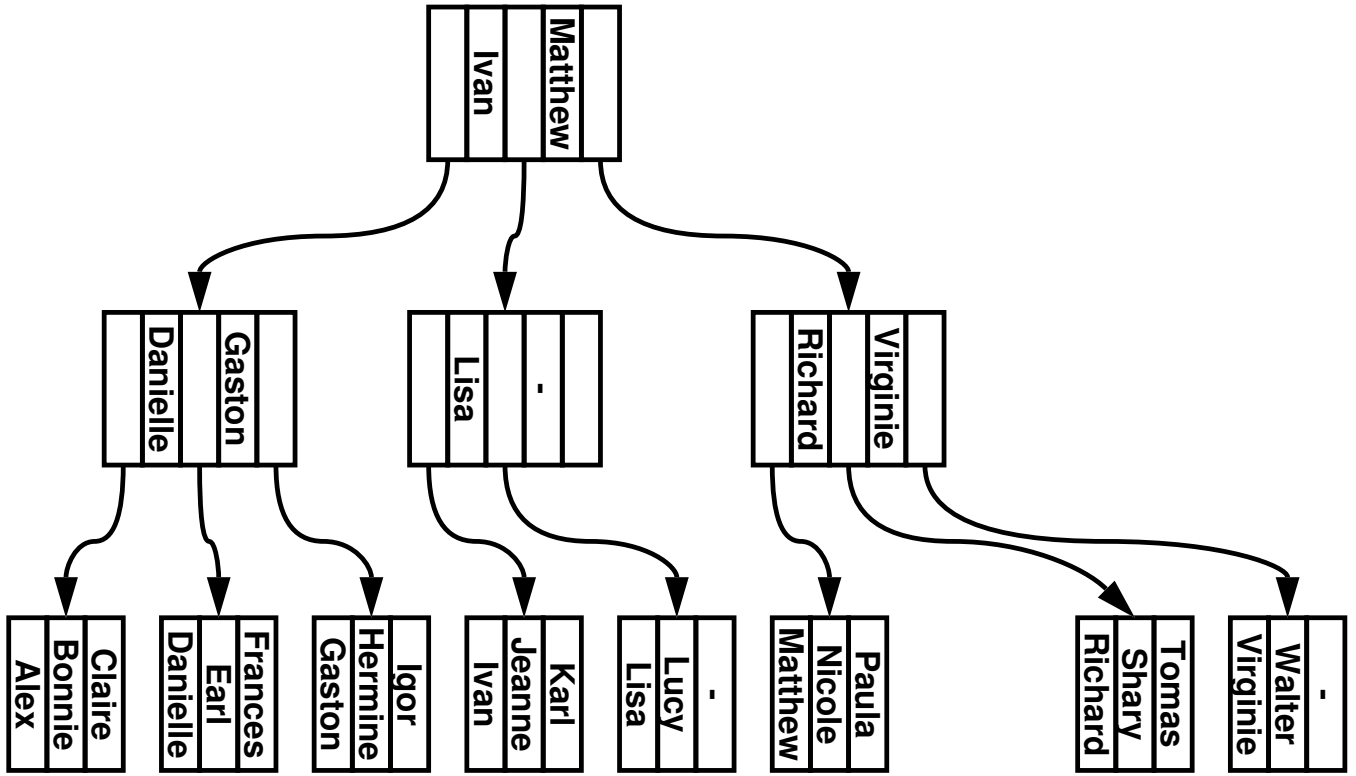
# B+ Trees (part 3)

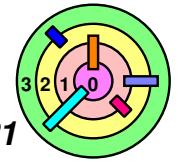
***Deletion:*** **e.g., "Otto"**



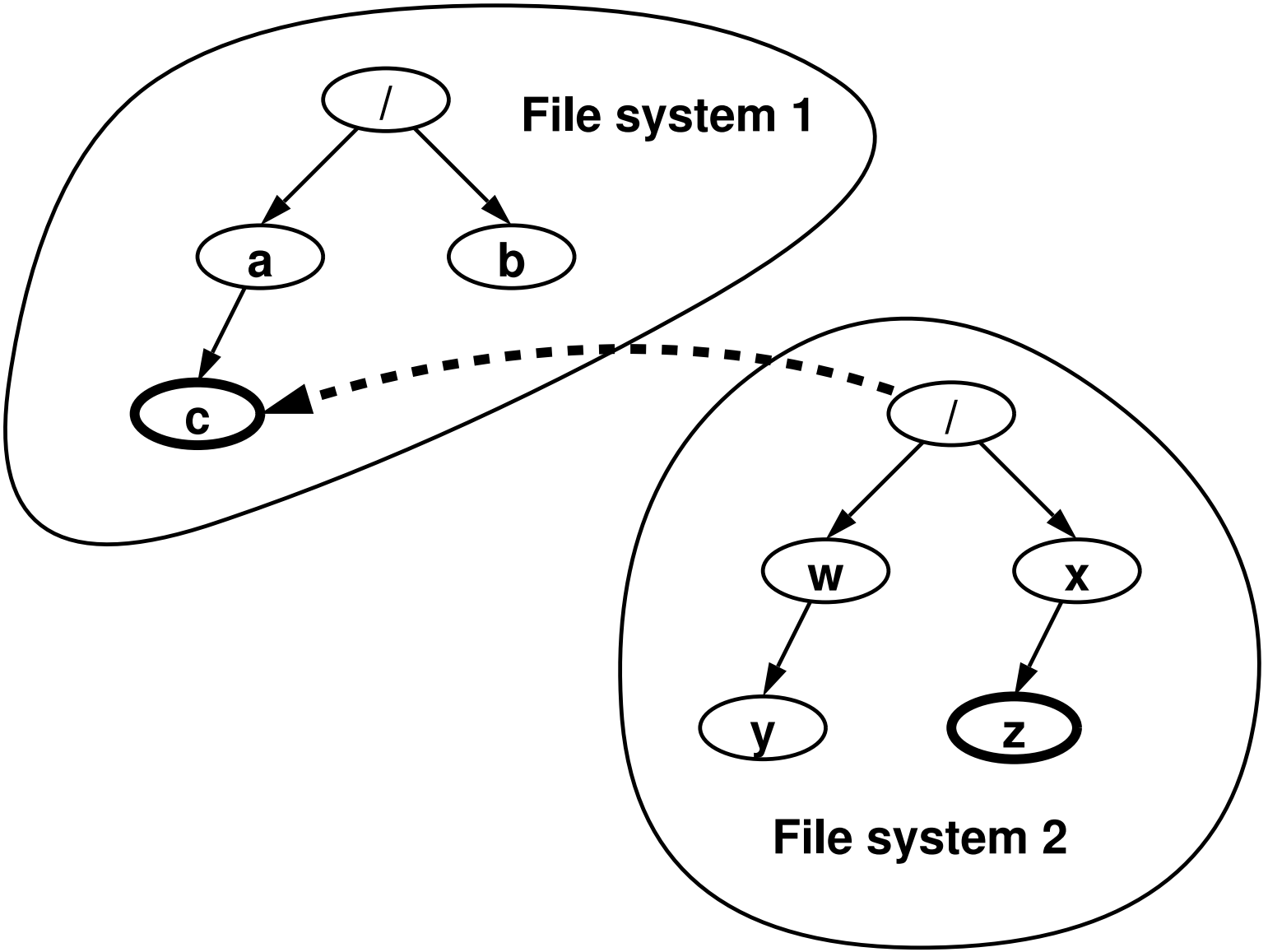
# B+ Trees (part 3)

- ***Deletion:*** **e.g., "Otto"**
  - **merge nodes if necessary**
    - **may decrease depth**



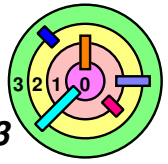



# Name-Space Management

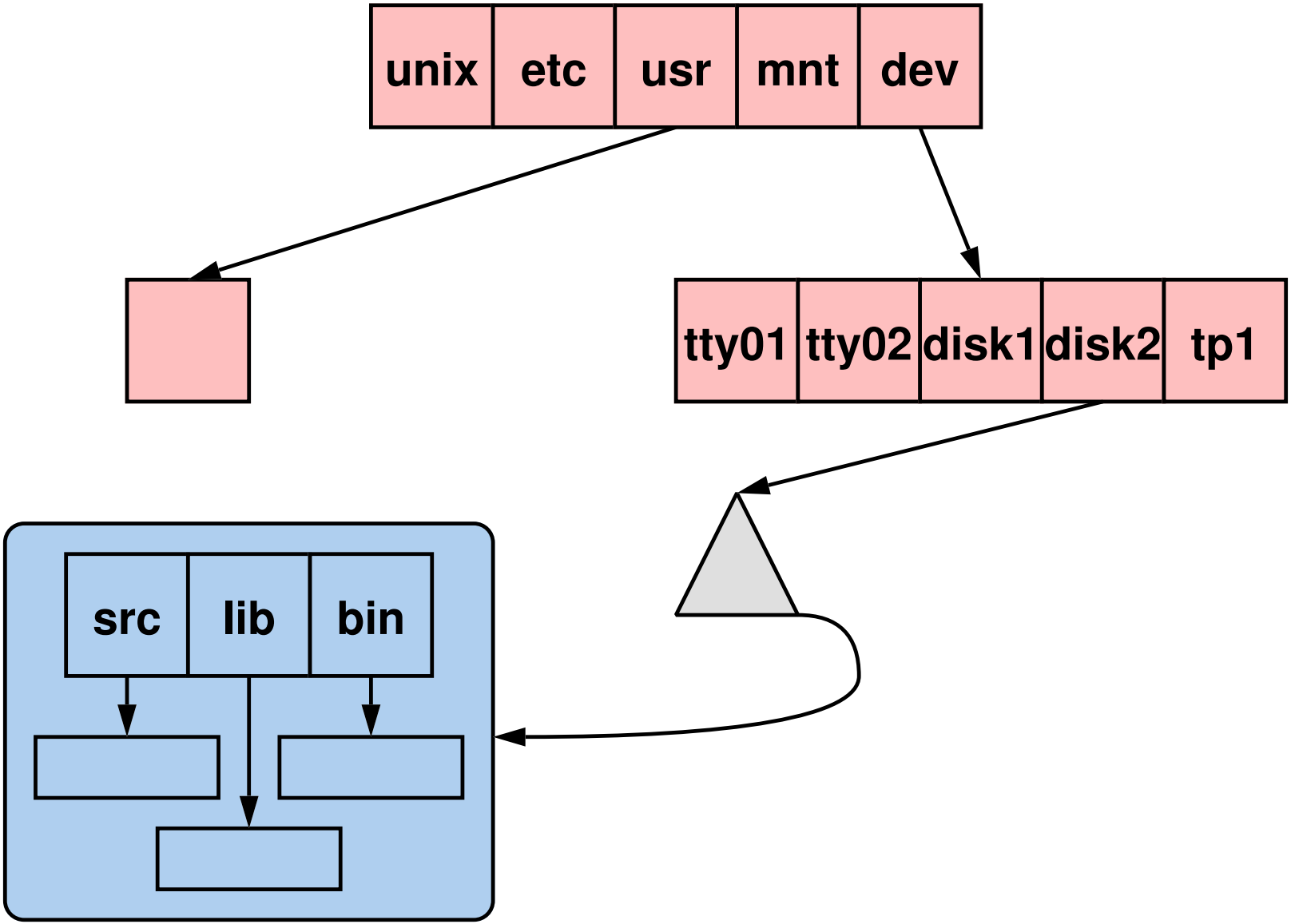


# Name-Space Management

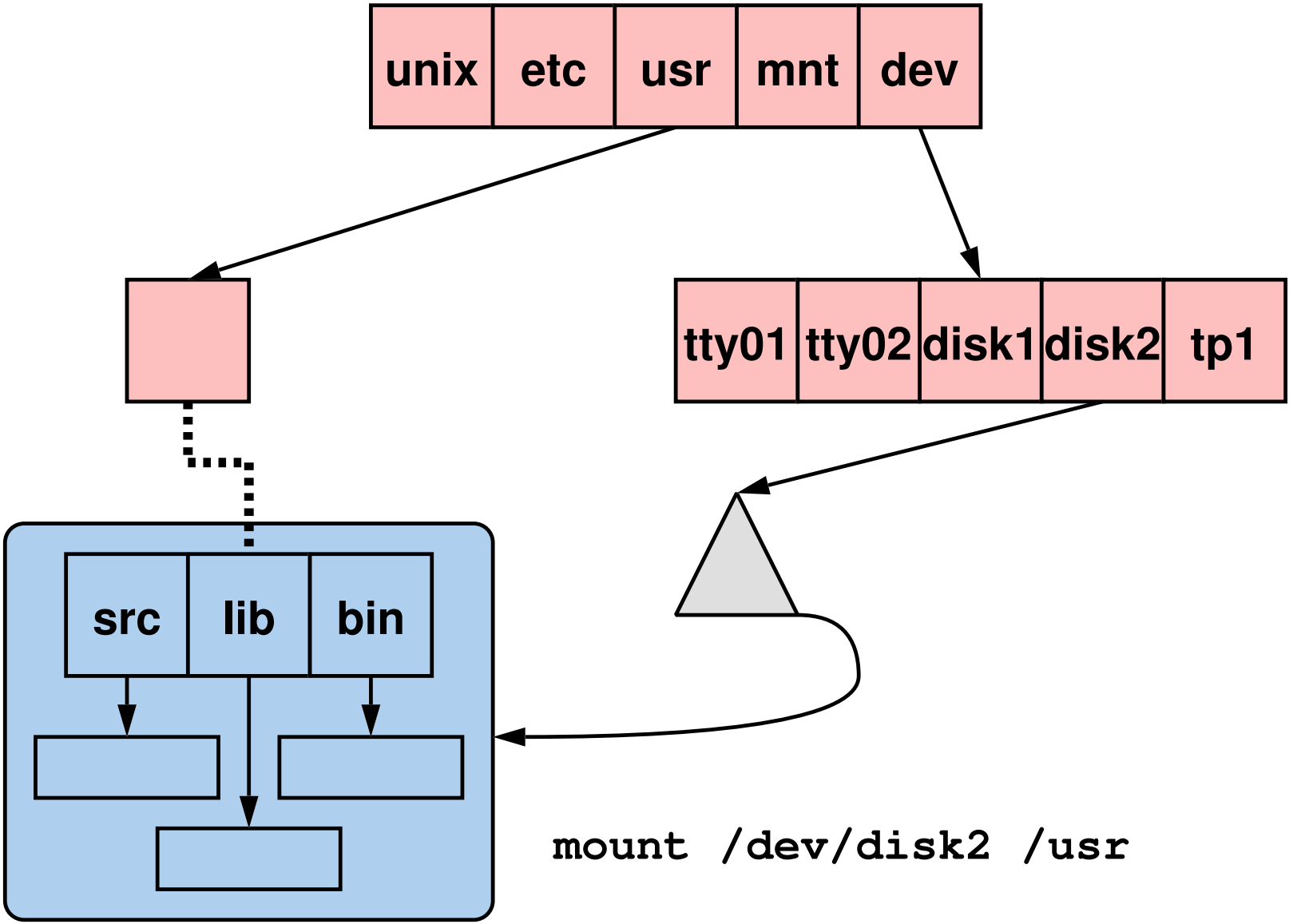
- Multiple partitions of hard drive
  - on Windows, you have C:, D:, etc.
  - on Unix, you have /dev/sda0 (ext2), /dev/sda1 (ext3), etc.
- USB (JFFS2), CDROM (ISO9660)
- Main challenge for name-space management
  - how do you make the name-space appear uniform?
    - Windows: drives
    - Unix: file system *mounting*
      - create an entry in the inode to point to the file system
      - only happen in *memory* (in the buffer cache) and not on disk



# Mount Points (1)



# Mount Points (2)



# File System Mounting

- `mount /dev/disk2 /usr`
  - `/usr/bin/bash` is to be located at `/dev/disk2/bin/bash`
- `mount /dev/usb0 /mnt/usb`
  - on Mac OS X, instead of `/mnt`, it uses `/Volumes`

# Weenix

- Try `MOUNTING=1` in `Config.mk`
  - may be after the semester is over
  - polymorphism