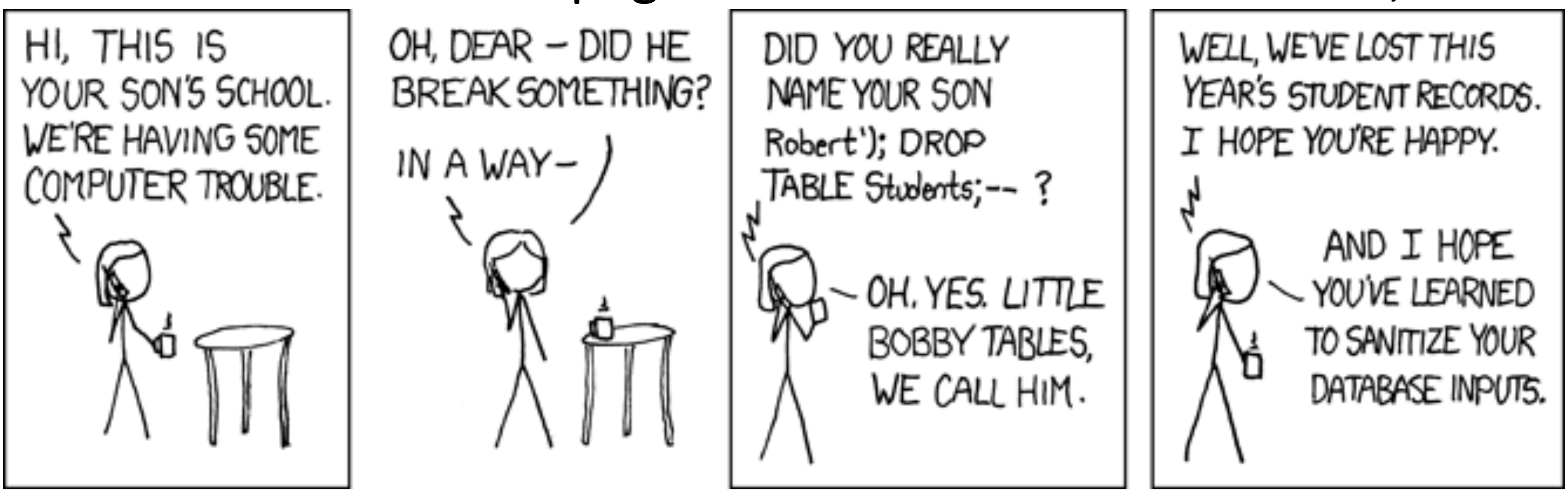
Constraints, Indices, B-Trees

Maintaining Integrity of Data

- You are creating a search engine for Rhodes' website, called Rhoogle.
- You have an SQL query:
  - "SELECT * FROM pages WHERE name='" + VAR + "';"



Maintaining Integrity of Data

- Data is ***dirty***.
- How does an application ensure that a database modification does not corrupt the tables?

- Two approaches:
  - Application programs check that database modifications are consistent.
  - Use the features provided by SQL.

Integrity Checking in SQL

- Data type constraints (including NOT NULL).
- PRIMARY KEY and UNIQUE constraints.
- FOREIGN KEY constraints.
- Constraints on attributes and tuples.
- Triggers (schema-level constraints).

Constraints and Queries

- Often, constraints involve attributes we often perform searches (SQL SELECTs) on.

- To speed up queries, DBs will often create ***indices*** automatically for you.

Indexes

- ***Index*** = data structure used to speed access to tuples of a relation, given values of one or more attributes.

Declaring Indexes

- No standard!
- Typical syntax:

```
CREATE INDEX MovieIdx ON
  Movie(MovieId);
CREATE INDEX CastsIdx ON
  Casts(ActorId, MovieId);
```

Types of Indexes

- **Primary:** index on a key
  - Used to enforce constraints
- **Secondary:** index on non-key attribute

Using Indexes: Equality Searches

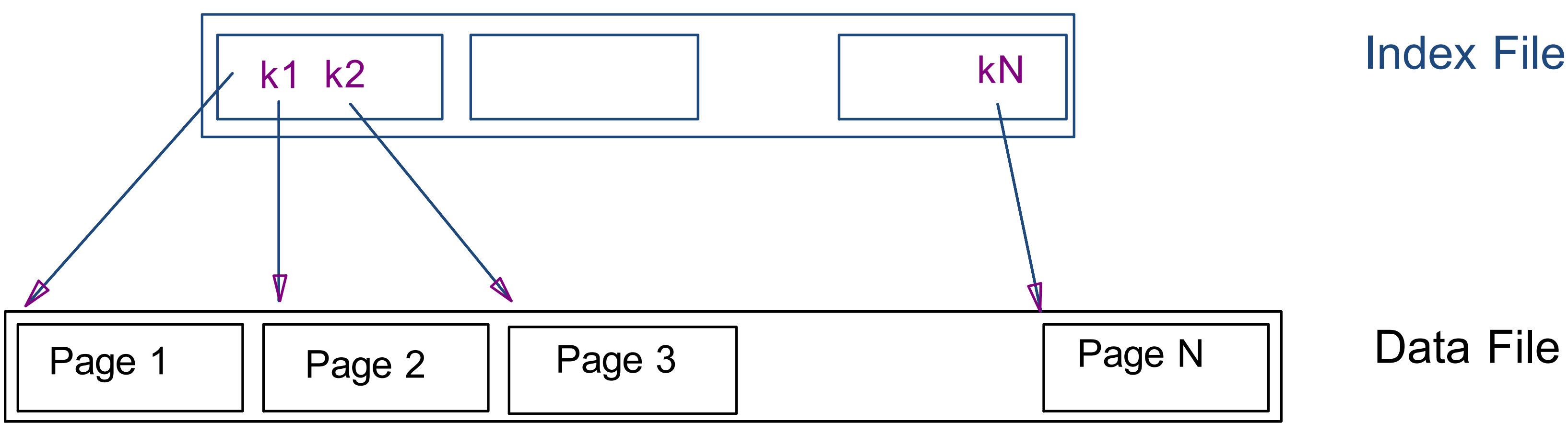
- Given a value *v*, the index takes us to only those tuples that have *v* in the attribute(s) of the index.
- What data structure would be useful here?

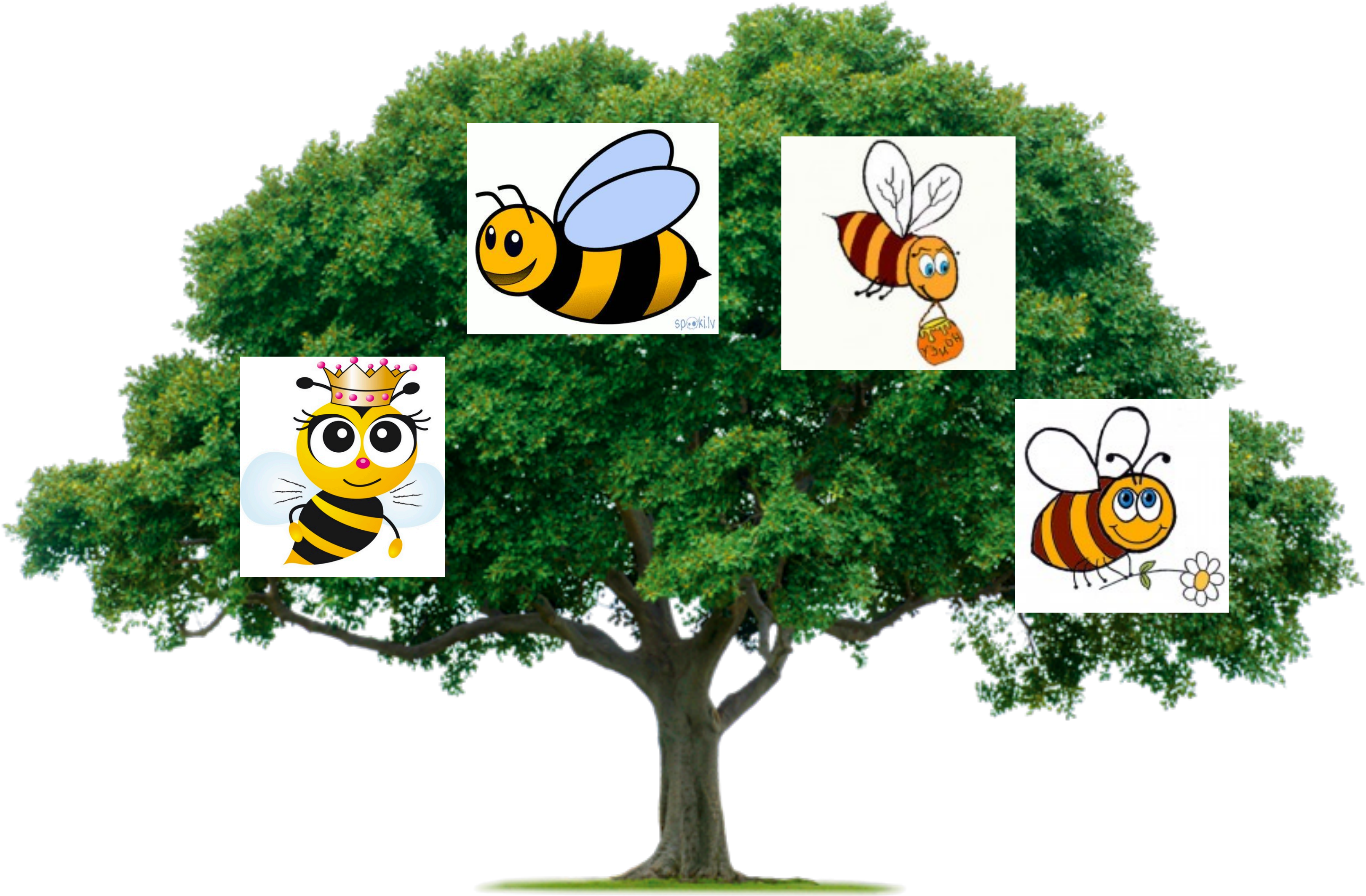
Using Indexes: Range Searches

- "Find all students with GPA > 3.0"
- What data structure(s) work here?

Range Searches

- "*Find all students with GPA > 3.0*"
- May be slow, even on sorted file
- Solution: Create an index file.





B-trees

- Extension of binary search trees to n-way search trees (where $n > 2$)
- Balanced (like red-black trees)

Why B-Trees Are So Great for DB Indexes

- DBs are usually on disk, not RAM
  - B-tree structure aligns with ***disk pages***
  - Hierarchical structure minimizes number of disk reads.
- Keeps info in sorted order for equality or range searches.
- Balanced tree structure gives fast searches, insertions, deletions.

Definition

- B-tree of order d is a (2d+1) tree:
  - Internal nodes have one more child (pointer) than data elements (keys). Leaf nodes have no children.
  - Root has between 1 and 2d data elements.
  - Non-root nodes have between d and 2d elements.
  - All leaves are at the same depth in the tree.
  - Has ***extended search property*** (binary search tree property extended to multiway tree)

Algorithms: Search

- Extrapolated from binary tree search algorithm.

Algorithms: Insert

- First, find ***leaf*** node where data would go.
- Insert(data, node):
  - If data can fit in node, add it to the node.
  - If causes overflow:
    - split node at the median value.
    - Everything less than median becomes new leaf node.
    - Everything greater than median becomes new leaf node.
    - Promote median to parent node; call insert(median, parent) [*may create new parent node if there is no parent*]

Algorithms: Delete

- Search for item to delete
- If at leaf node, delete the item
  - Rebalance up from leaf if necessary
- If at internal node, swap with largest child in left sub-tree (analogous to BST deletion swap)
  - Rebalance if necessary