B-Trees
Problem: Data base too big to fit memory
Disk reads are slow

Example: 1,000,000 records on disk
Binary search might take
20 disk reads
Disk reads are done in blocks

Example: One block read can retrieve 100 records
1,000,000 Records
1,000,000 Records
DEF: A B-Tree of order m is an m-way tree such that
1. All leaf nodes are at the same level.
2. All non-leaf nodes (except the root) have at most m and at least m/2 children.
3. The number of keys is one less than the number of children for non-leaf nodes and at most m-1 and at least m/2 for leaf nodes.
4. The root may have as few as 2 children unless the tree is the root alone.
Example for $m = 5$

DEF: A B-Tree of order 5 is an 5-way tree such that

1. All leaf nodes are at the same level.
2. All non-leaf nodes (except the root) have at most 5 and at least 2 children.
3. The number of keys is one less than the number of children for non-leaf nodes and at most 4 and at least 2 for leaf nodes.
4. The root may have as few as 2 children unless the tree is the root alone.
Creating a B-tree of order 5

AGFBKDHMJESIRXCLNTUP
Creating a B-tree of order 5

AGFBKDHMJESIRXCLNTUP

A B F G
Creating a B-tree of order 5

AGFBK DHMJESIRXCLNPUTP

A   B   F   G   K
Creating a B-tree of order 5

A G F B K D H M J E S I R X C L N T U P
Creating a B-tree of order 5

AGFBKDHMJESIRXCLNTUP
Creating a B-tree of order 5

A G F B K D H M J E S I R X C L N T U P

F

A B D G H J K M
Creating a B-tree of order 5

A G F B K D H M J E S I R X C L N T U P
Creating a B-tree of order 5

AGFBKDHMJESIRXCLNTUP
Creating a B-tree of order 5

A G F B K D H M J E S I R X C L N T U P

Diagram:

- Root node: F J
- Left subtree: A B D E
- Right subtree: G H I
- Rightmost subtree: K M R S X
Creating a B-tree of order 5

AGFBKDHMJEESIRXCLNTUP
Creating a B-tree of order 5

AGFBKDHJMIESIRXCLNTUP
Creating a B-tree of order 5

AGFBKDHMJSIRXCLNTUP
Creating a B-tree of order 5

AGFBKDHMJESIRXCLNTUP
Creating a B-tree of order 5

AGFBKDHMJESIRXCLNTUP

A B
D E
G H I
K L M N P
S T U X
Creating a B-tree of order 5

AGFBKDHMJESIRXCLNTUP

A B  D E  G H I  K L  N P  S T U X
Creating a B-tree of order 5

AGFBKDHMJESIRXCLNTUP

A B C D E F G H I J K L M N P S T U X
Deleting Nodes

- Delete E from leaf node
DeleTng Nodes

• Delete E
Deleting Nodes

- Borrow from a neighbor
Deleting Nodes

- Delete F — but can’t borrow from a neighbor
Deleting Nodes

Combine and push the problem up one level
Deleting Nodes

Can’t borrow so combine
Deleting Nodes

Delete M from non-leaf node
Note: immediate predecessor in non-leaf
Is always in a leaf.
Deleting Nodes

Delete M from non-leaf node

Overwrite M with immediate predecessor
Deleting Nodes

Borrow from a neighbor