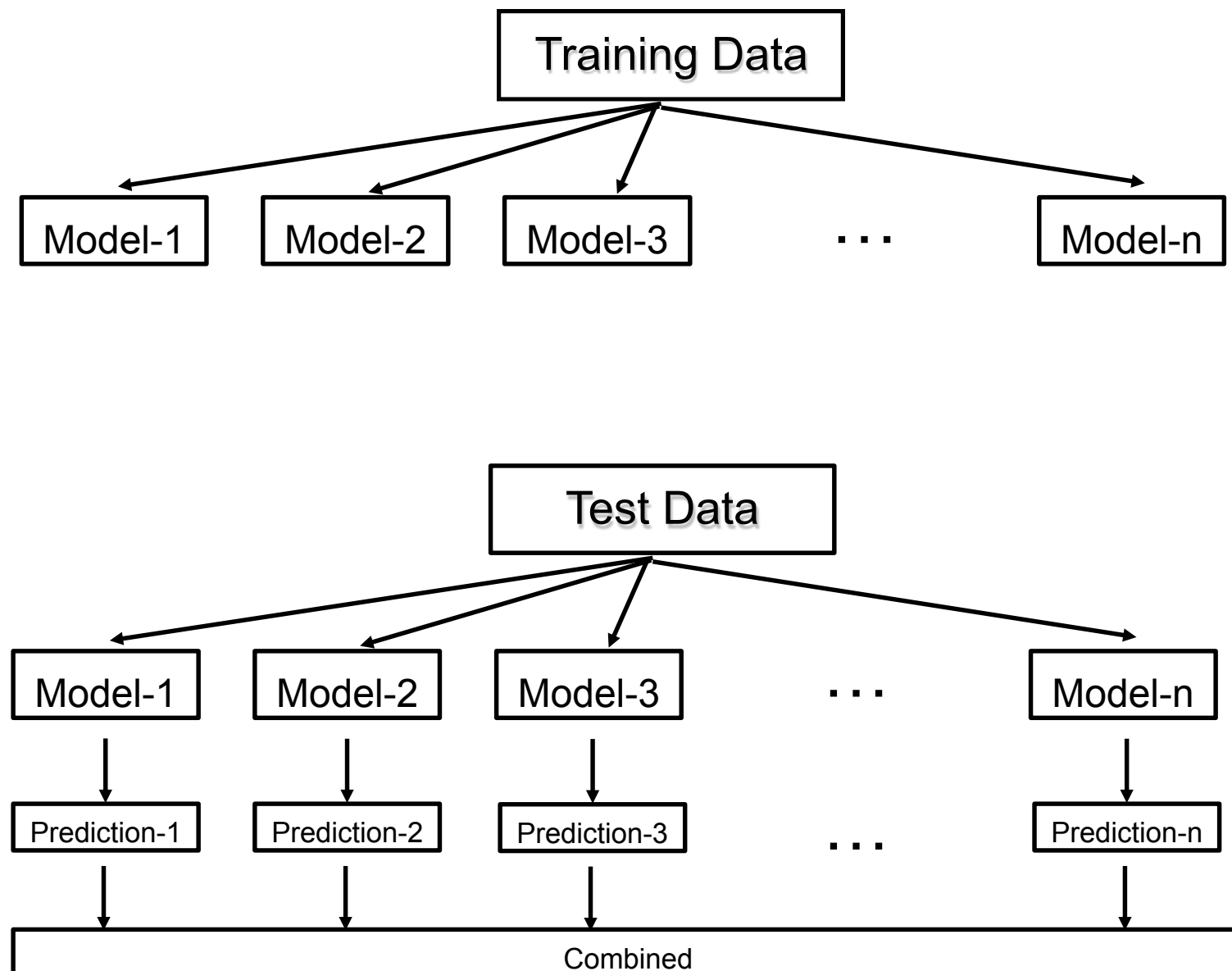


Ensemble Methods

- Ensembles are machine learning methods for combining predictions from multiple separate models.
- The central motivation is rooted under the belief that a committee of experts working together can perform better than a single expert.

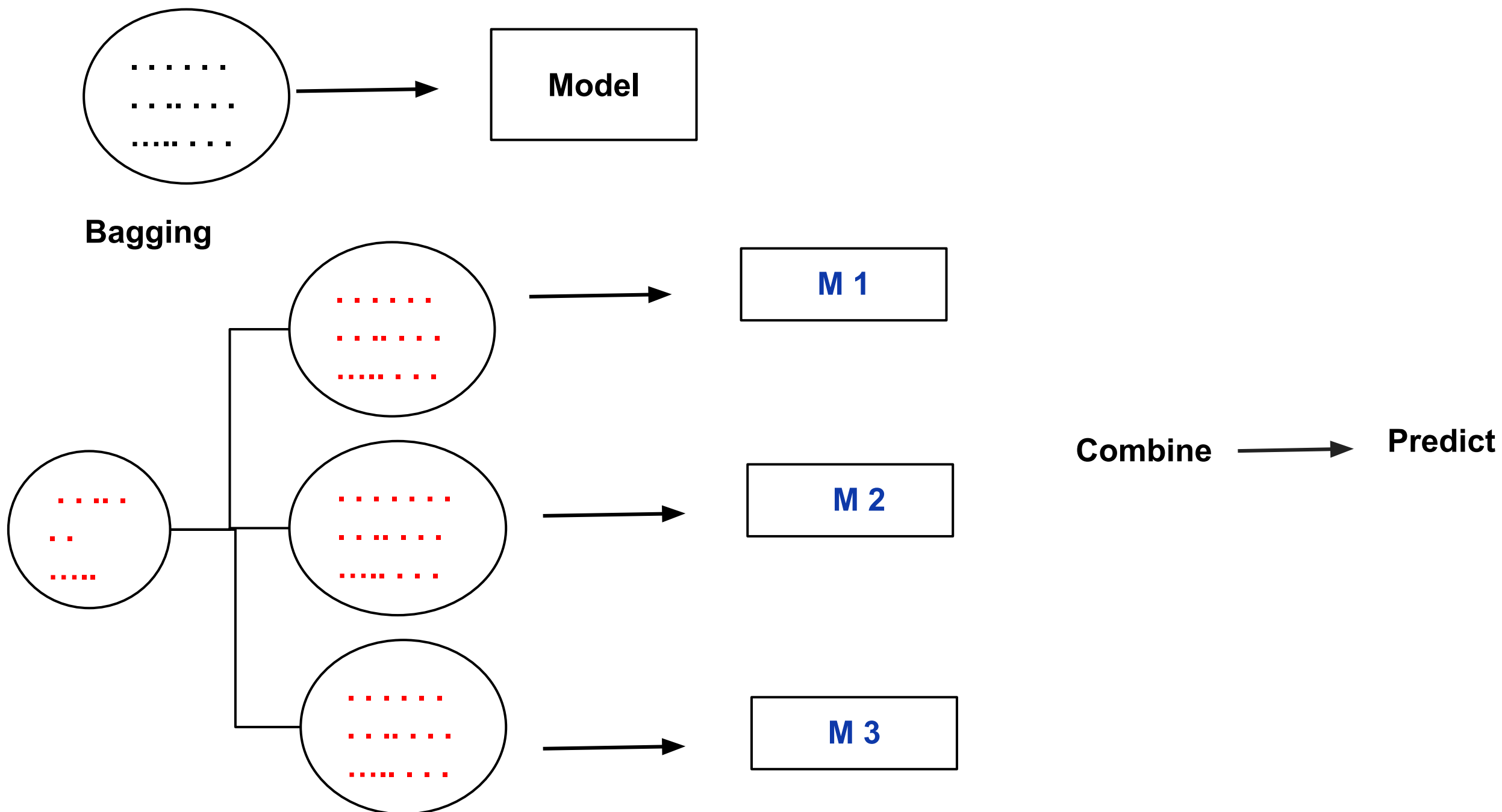


Prediction

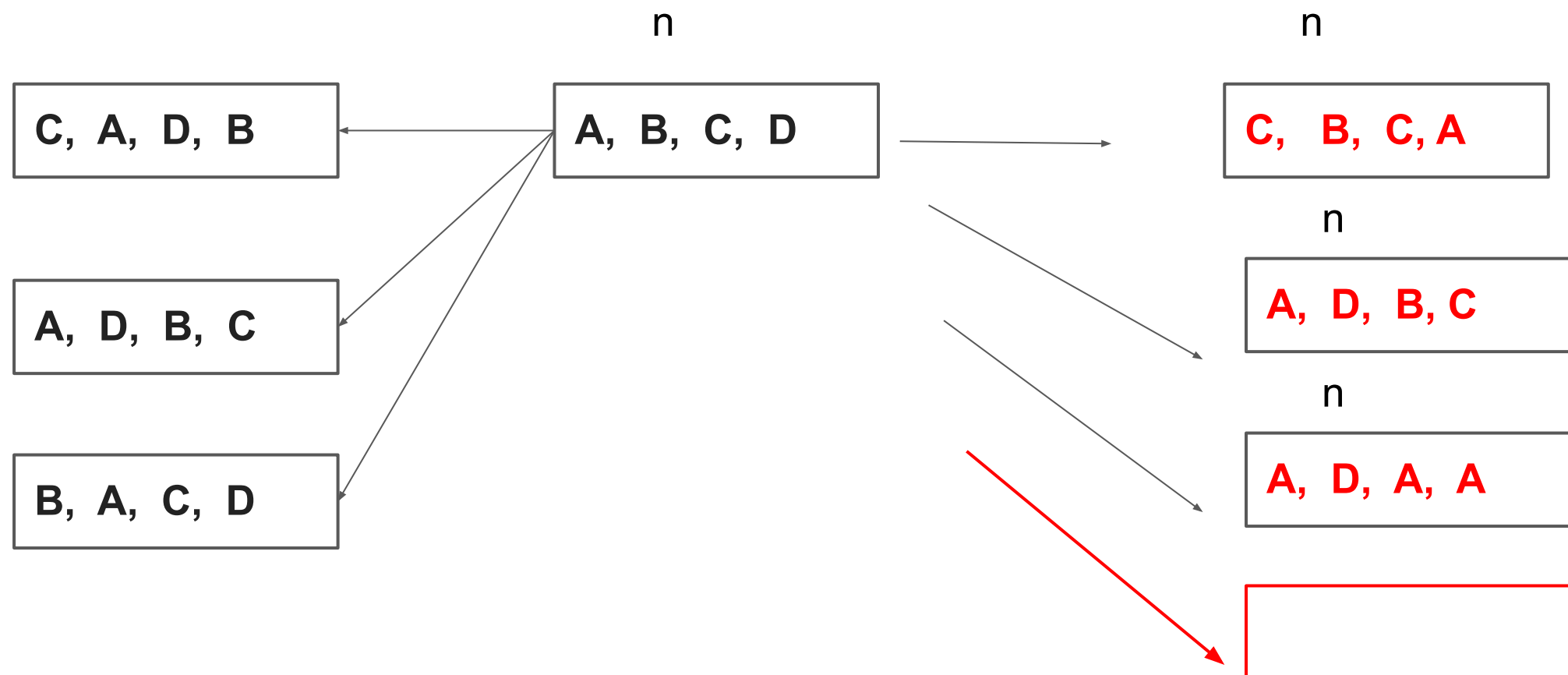
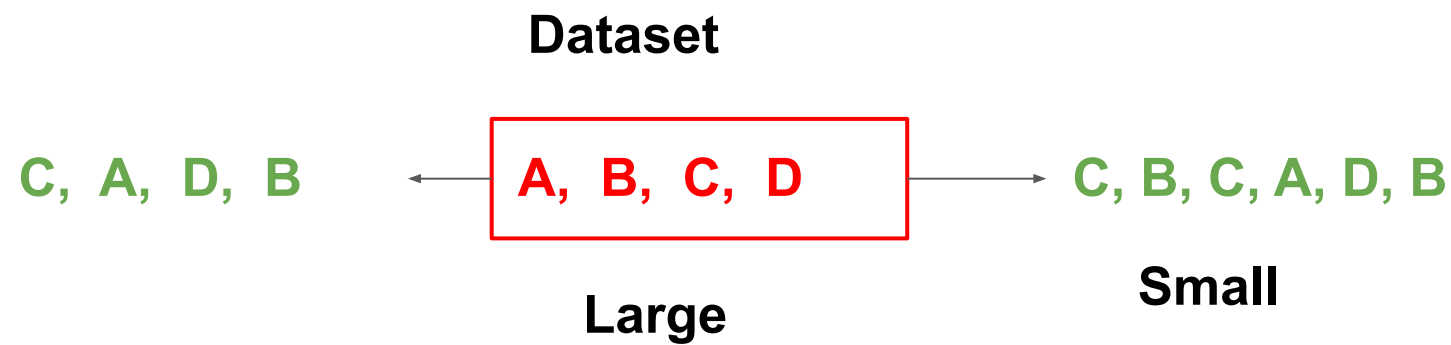
Ensemble Methods

	90%	90%	90%	90%	90%	
Truth	M1	M2	M3	M10	
Y	✓	✓	✓	✓	X	✓
Y	X	X	X	X	X	✓
N	✓	✓	✓	X	X	✓
..	✓	X	✓	X	X	✓
...	✓	✓	✓	✓	✓
...	✓	✓	✓	✓	✓	...
Y	✓	✓	✓	✓		...
N	✓	✓	✓	✓	✓	...

Bagging



Why Sampling with Replacement?



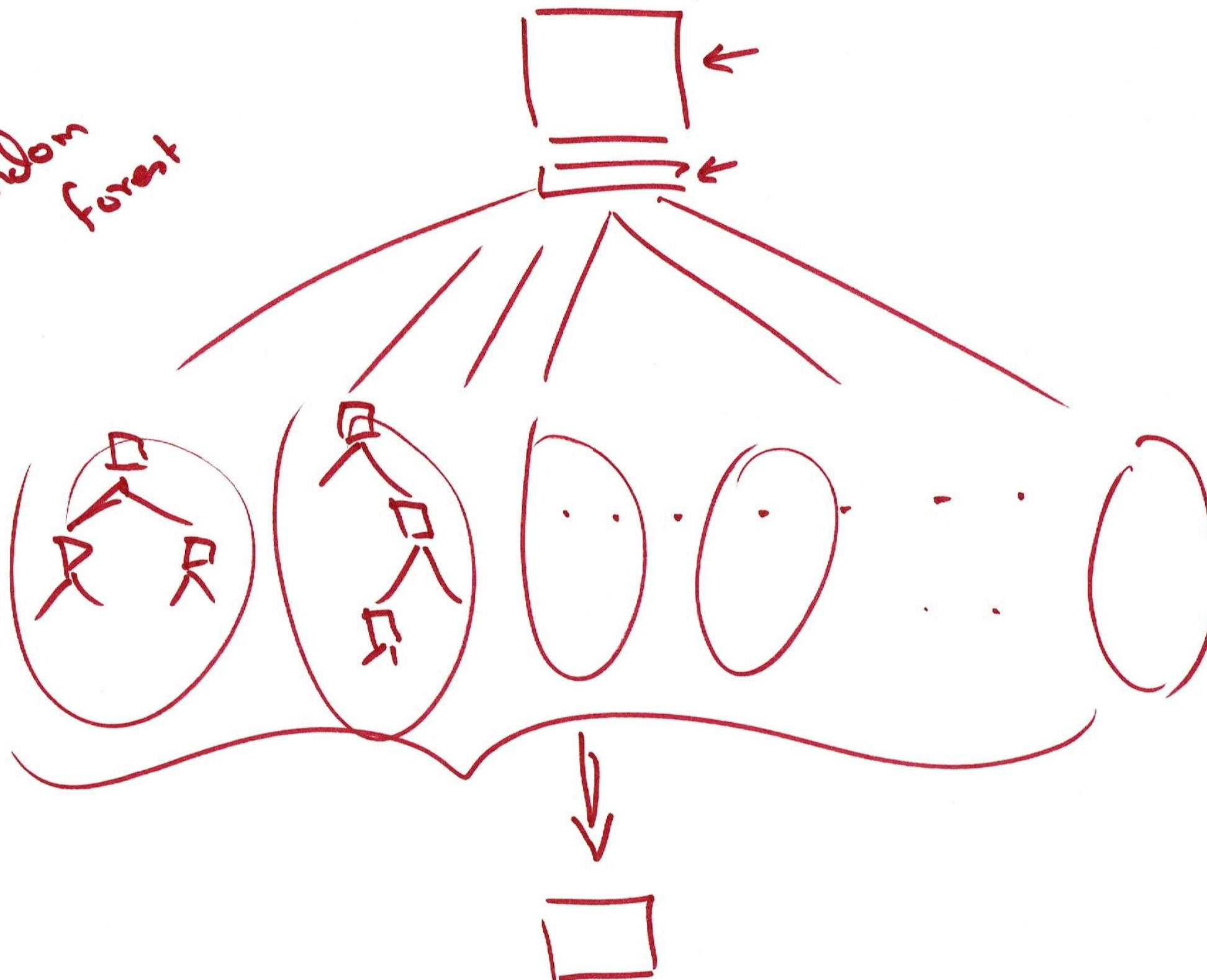
[illegible]

```
graph TD; A[ ] --> B[ ]; A --> C[ ]; B --> D[ ]; B --> E[ ]; C --> F[ ]; C --> G[ ]
```

Tree to a Forest

- Decision trees are very sensitive to even small changes in the data - usually called unstable.
- Can we get a whole bunch of decision trees to work together to yield a better and more robust prediction?
- Then for prediction we could use the mean for regression trees and mode for classification trees
- While individual trees are tend to over-fit training data, averaging corrects this.

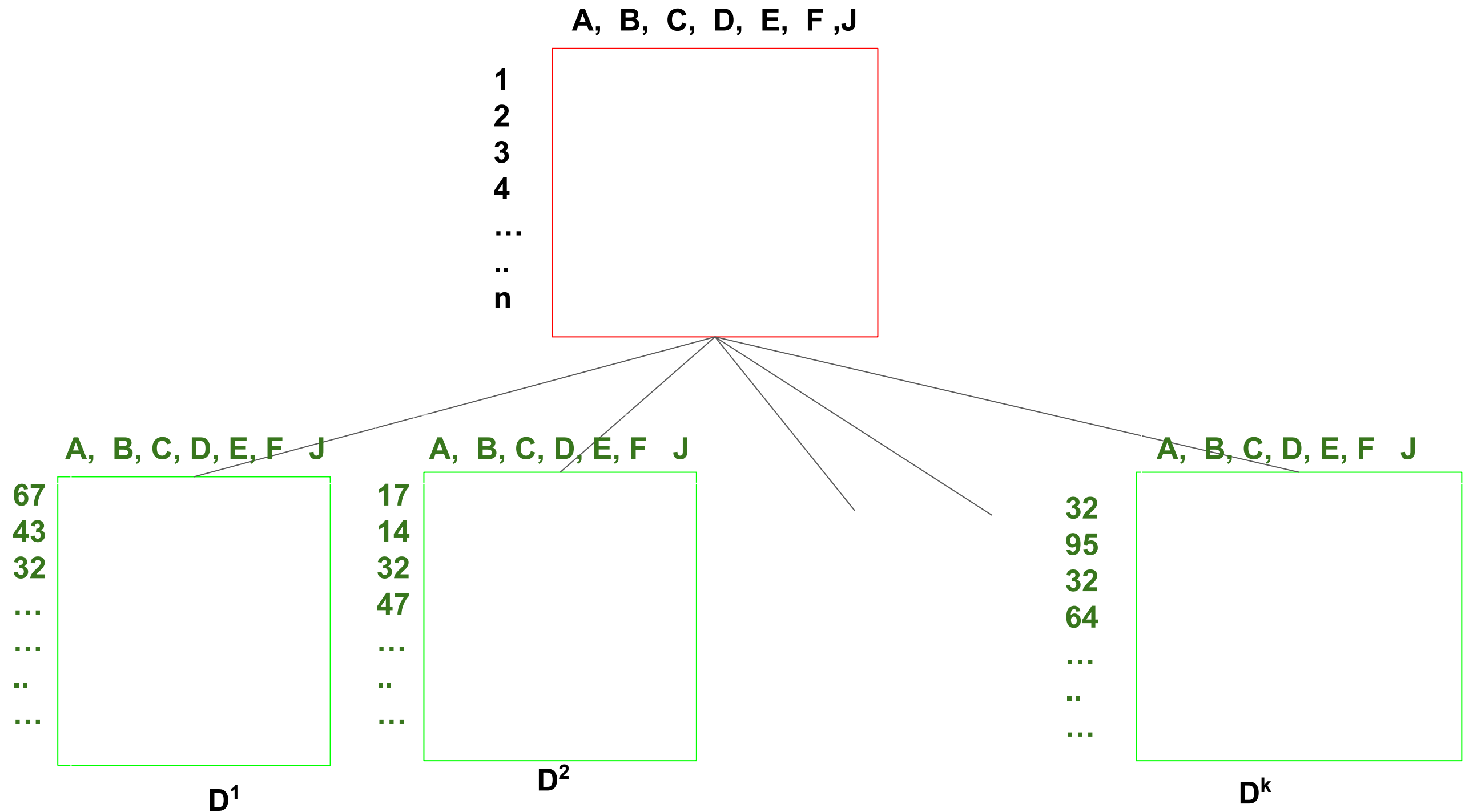
Random forest



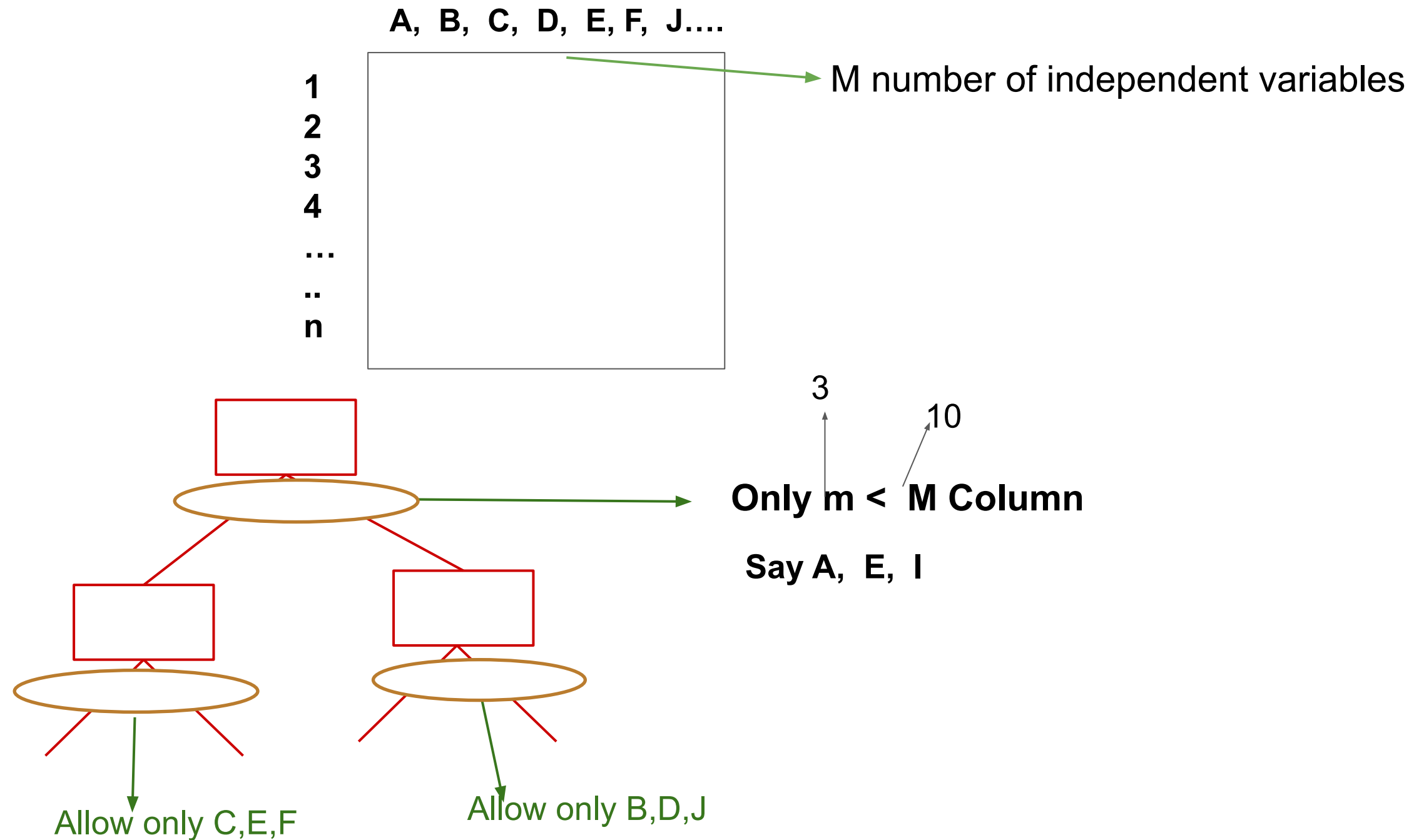
The General Ideas

- The general procedure of using multiple models (trees, in this case) to obtain better predictive performance is called ensemble learning.
- Bootstrap aggregating. also called bagging:
 - Generate new training subsets of the original, each of the same size (usually the size of the data) by sampling with replacement.
 - By sampling with replacement, some observations may be repeated in each subset.





Random Forest



Random Forest



Random forests

- 
- Random Sampling with replacement
 - For each subset build a decision tree. However, only use m randomly pick independent variables for each node's branching possibilities. 
 - Do not prune
 - While predicting:
 - Use each tree to make individual predictions
 - Combine predictions using voting:
 - Means for regression
 - Modes for classification
- 
- 

Random Forest

Say $M = 10 \Rightarrow A B C D \bigcirc \bigcirc \bigcirc \textcircled{J}$

