



UNSUPERVISED LEARNING IN PYTHON

Unsupervised learning



Unsupervised learning

- Unsupervised learning finds patterns in data
- E.g. *clustering* customers by their purchases
- Compressing the data using purchase patterns (*dimension reduction*)

Supervised vs unsupervised learning

- *Supervised* learning finds patterns for a prediction task
- E.g. classify tumors as benign or cancerous (*labels*)
- Unsupervised learning finds patterns in data
- ... but *without* a specific prediction task in mind



Iris dataset

- Measurements of many iris plants
- 3 species of iris: setosa, versicolor, virginica
- Petal length, petal width, sepal length, sepal width (the *features* of the dataset)



Arrays, features & samples

- 2D NumPy array
- Columns are measurements (the *features*)
- Rows represent iris plants (the *samples*)



Iris data is 4-dimensional

- Iris samples are points in 4 dimensional space
- Dimension = number of features
- Dimension too high to visualize!
- ... but unsupervised learning gives insight



k-means clustering

- Finds clusters of samples
- Number of clusters must be specified
- Implemented in **sklearn** ("scikit-learn")



k-means clustering with scikit-learn

```
In [1]: print(samples)
[[ 5.   3.3  1.4  0.2]
 [ 5.   3.5  1.3  0.3]
 [ 4.9  2.4  3.3  1. ]
 [ 6.3  2.8  5.1  1.5]
 ...
 [ 7.2  3.2  6.   1.8]]
```

```
In [2]: from sklearn.cluster import KMeans
```

```
In [3]: model = KMeans(n_clusters=3)
```

```
In [4]: model.fit(samples)
```

```
Out[4]: KMeans(algorithm='auto', ...)
```

```
In [5]: labels = model.predict(samples)
```

```
In [6]: print(labels)
```

```
[0 0 1 1 0 1 2 1 0 1 ...]
```


Cluster labels for new samples

- New samples can be assigned to existing clusters
- k-means remembers the mean of each cluster (the "centroids")
- Finds the nearest centroid to each new sample



Cluster labels for new samples

```
In [7]: print(new_samples)
[[ 5.7  4.4  1.5  0.4]
 [ 6.5  3.   5.5  1.8]
 [ 5.8  2.7  5.1  1.9]]

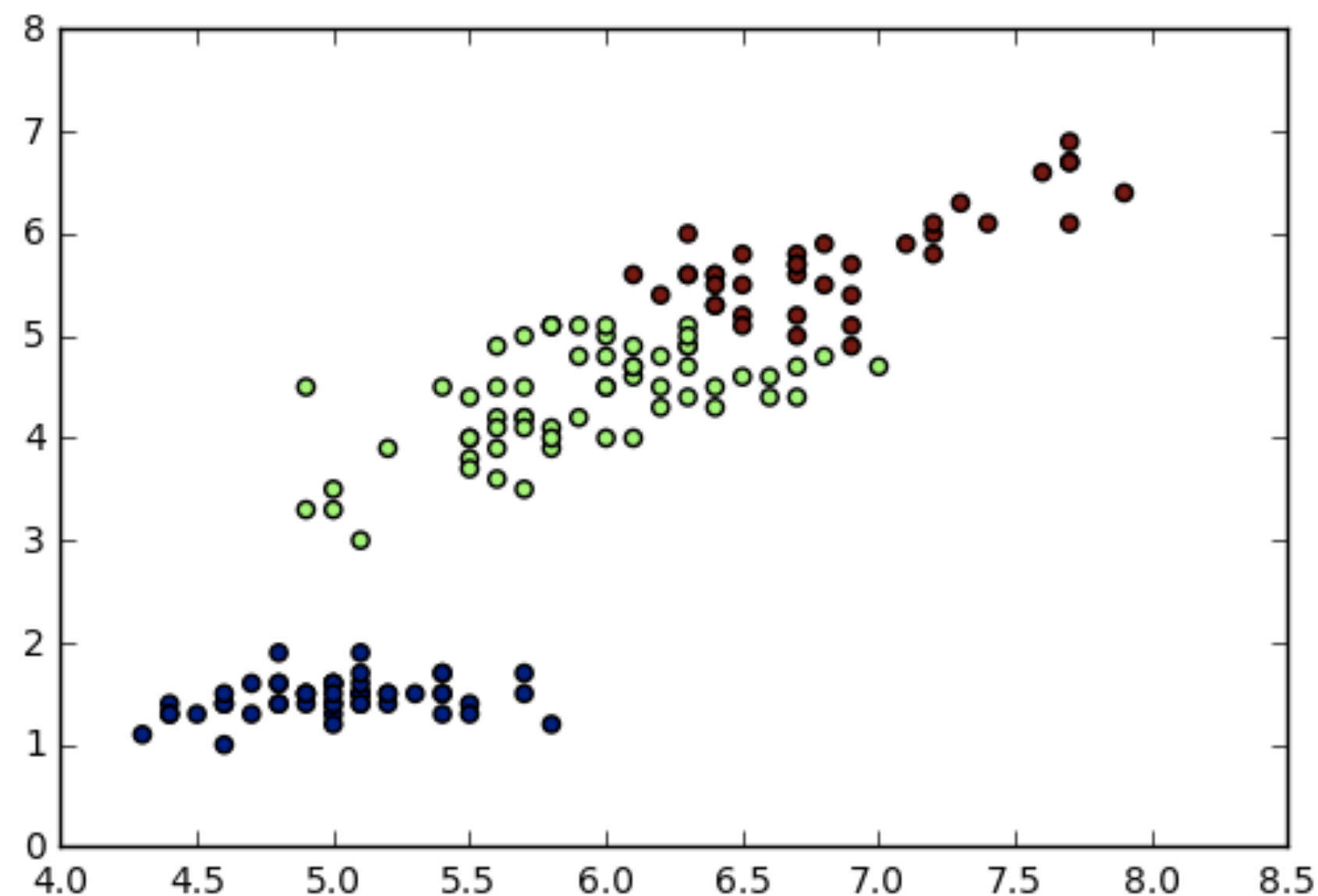
In [8]: new_labels = model.predict(new_samples)

In [9]: print(new_labels)
[0 2 1]
```



Scatter plots

- Scatter plot of sepal length vs petal length
- Each point represents an iris sample
- Color points by cluster labels
- PyPlot (`matplotlib.pyplot`)





Scatter plots

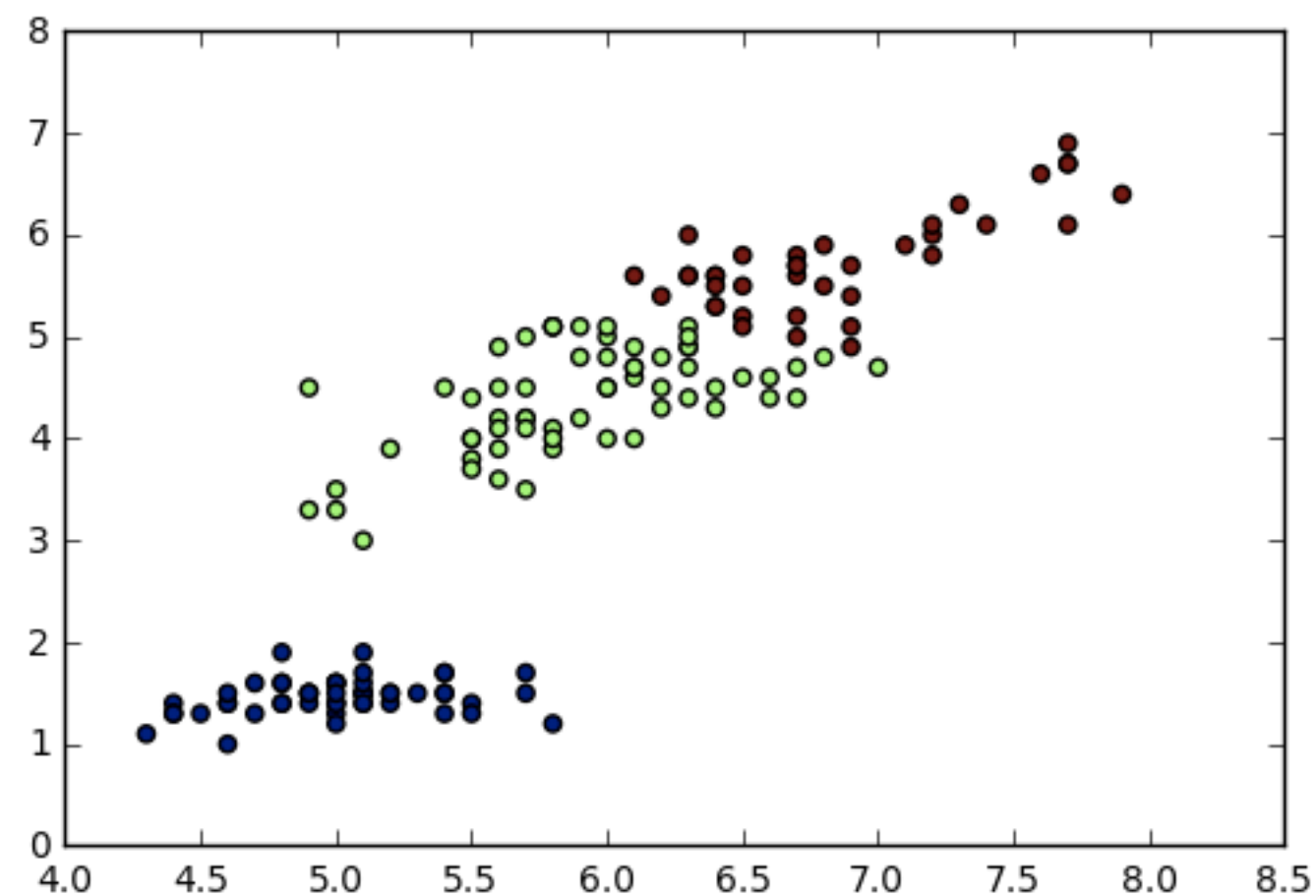
```
In [1]: import matplotlib.pyplot as plt
```

```
In [2]: xs = samples[:,0]
```

```
In [3]: ys = samples[:,2]
```

```
In [4]: plt.scatter(xs, ys, c=labels)
```

```
In [5]: plt.show()
```





PYTHON UNSUPERVISED LEARNING

Let's practice!



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Evaluating a clustering



Evaluating a clustering

- Can check correspondence with e.g. iris species
- ... but what if there are no species to check against?
- Measure quality of a clustering
- Informs choice of how many clusters to look for



Iris: clusters vs species

- k-means found 3 clusters amongst the iris samples
- Do the clusters correspond to the species?

species labels	setosa	versicolor	virginica
0	0	2	36
1	50	0	0
2	0	48	14



Cross tabulation with pandas

- Clusters vs species is a "cross-tabulation"
- Use the **pandas** library
- Given the species of each sample as a list **species**

```
In [1]: print(species)
['setosa', 'setosa', 'versicolor', 'virginica', ... ]
```



Aligning labels and species

```
In [2]: import pandas as pd
```

```
In [3]: df = pd.DataFrame({'labels': labels, 'species': species})
```

```
In [4]: print(df)
```

	labels	species
0	1	setosa
1	1	setosa
2	2	versicolor
3	2	virginica
4	1	setosa
...		



Crosstab of labels and species

```
In [5]: ct = pd.crosstab(df['labels'], df['species'])
```

```
In [6]: print(ct)
```

species	setosa	versicolor	virginica
labels			
0	0	2	36
1	50	0	0
2	0	48	14

How to evaluate a clustering, if there were no species information?

Measuring clustering quality

- Using only samples and their cluster labels
- A good clustering has tight clusters
- ... and samples in each cluster bunched together



Inertia measures clustering quality

- Measures how spread out the clusters are (*lower* is better)
- Distance from each sample to centroid of its cluster
- After `fit()`, available as attribute `inertia_`
- k-means attempts to minimize the inertia when choosing clusters

```
In [1]: from sklearn.cluster import KMeans
```

```
In [2]: model = KMeans(n_clusters=3)
```

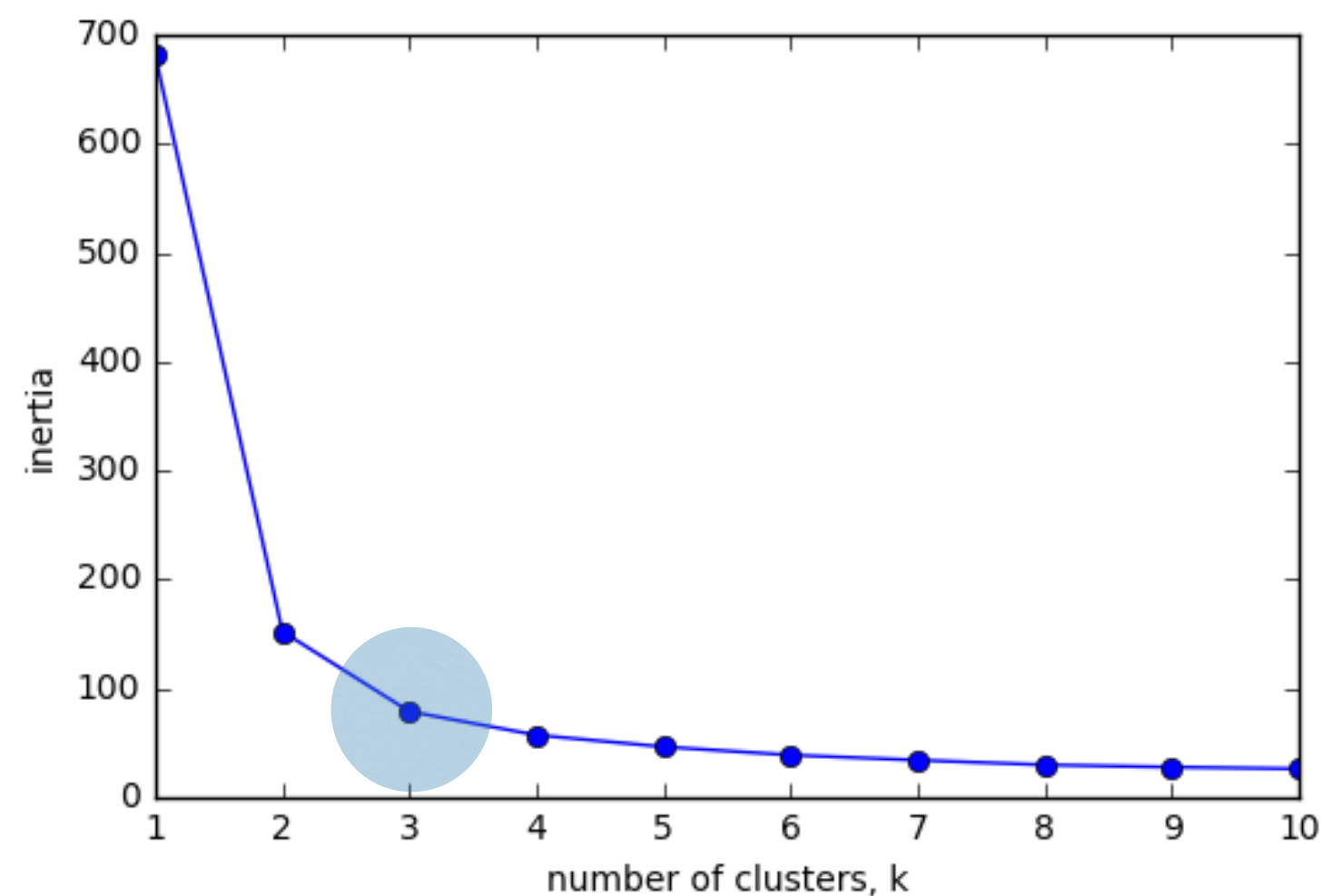
```
In [3]: model.fit(samples)
```

```
In [4]: print(model.inertia_)  
78.9408414261
```



The number of clusters

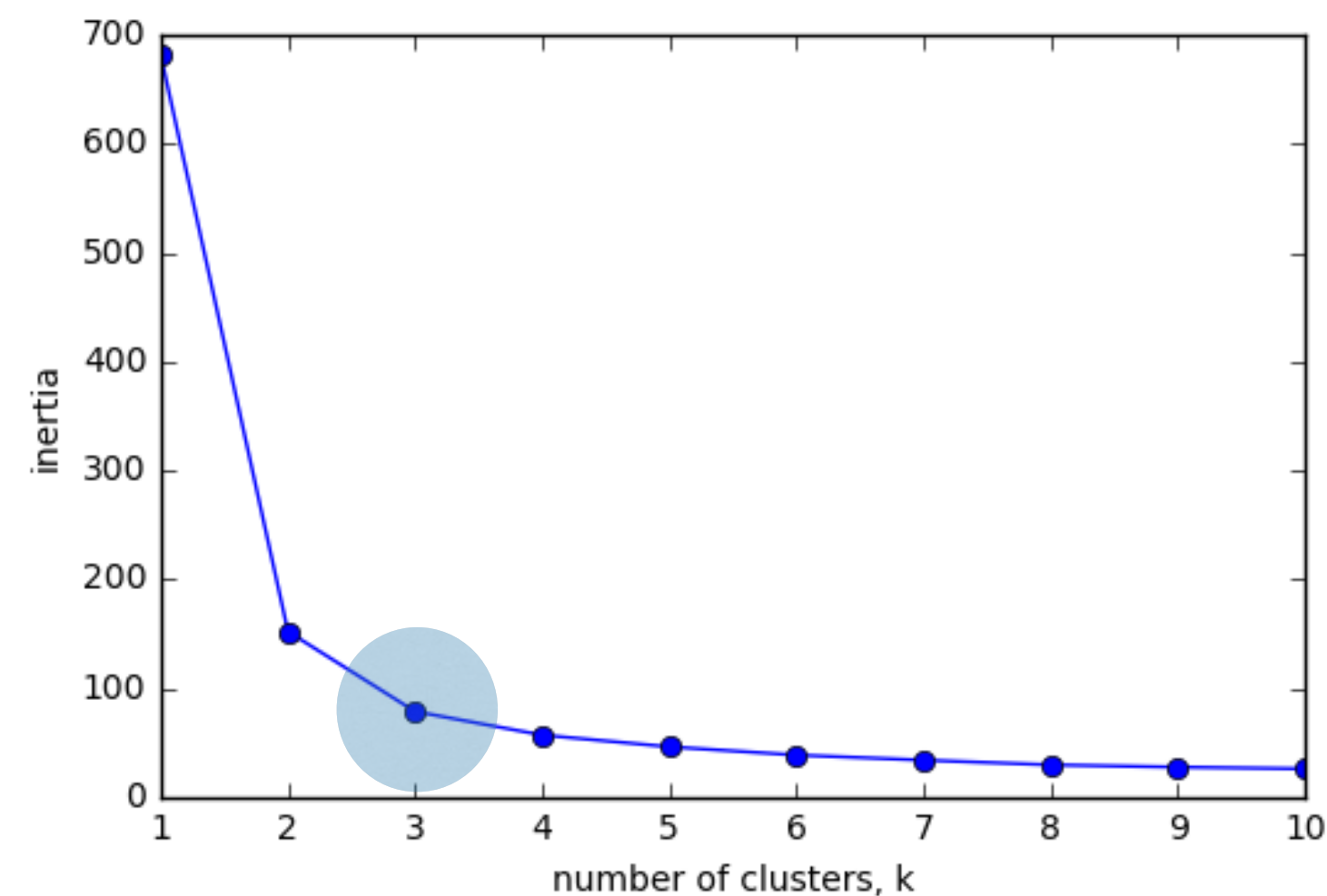
- Clusterings of the iris dataset with different numbers of clusters
- More clusters means lower inertia
- What is the best number of clusters?





How many clusters to choose?

- A good clustering has tight clusters (so low inertia)
- ... but not too many clusters!
- Choose an "elbow" in the inertia plot
- Where inertia begins to decrease more slowly
- E.g. for iris dataset, 3 is a good choice





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Transforming features for better clusterings



Piedmont wines dataset

- 178 samples from 3 distinct varieties of red wine: *Barolo*, *Grignolino* and *Barbera*
- Features measure chemical composition e.g. alcohol content
- ... also visual properties like “color intensity”



Clustering the wines

```
In [1]: from sklearn.cluster import KMeans
```

```
In [2]: model = KMeans(n_clusters=3)
```

```
In [3]: labels = model.fit_predict(samples)
```



Clusters vs. varieties

```
In [4]: df = pd.DataFrame({'labels': labels,
    ....:                  'varieties': varieties})

In [5]: ct = pd.crosstab(df['labels'], df['varieties'])

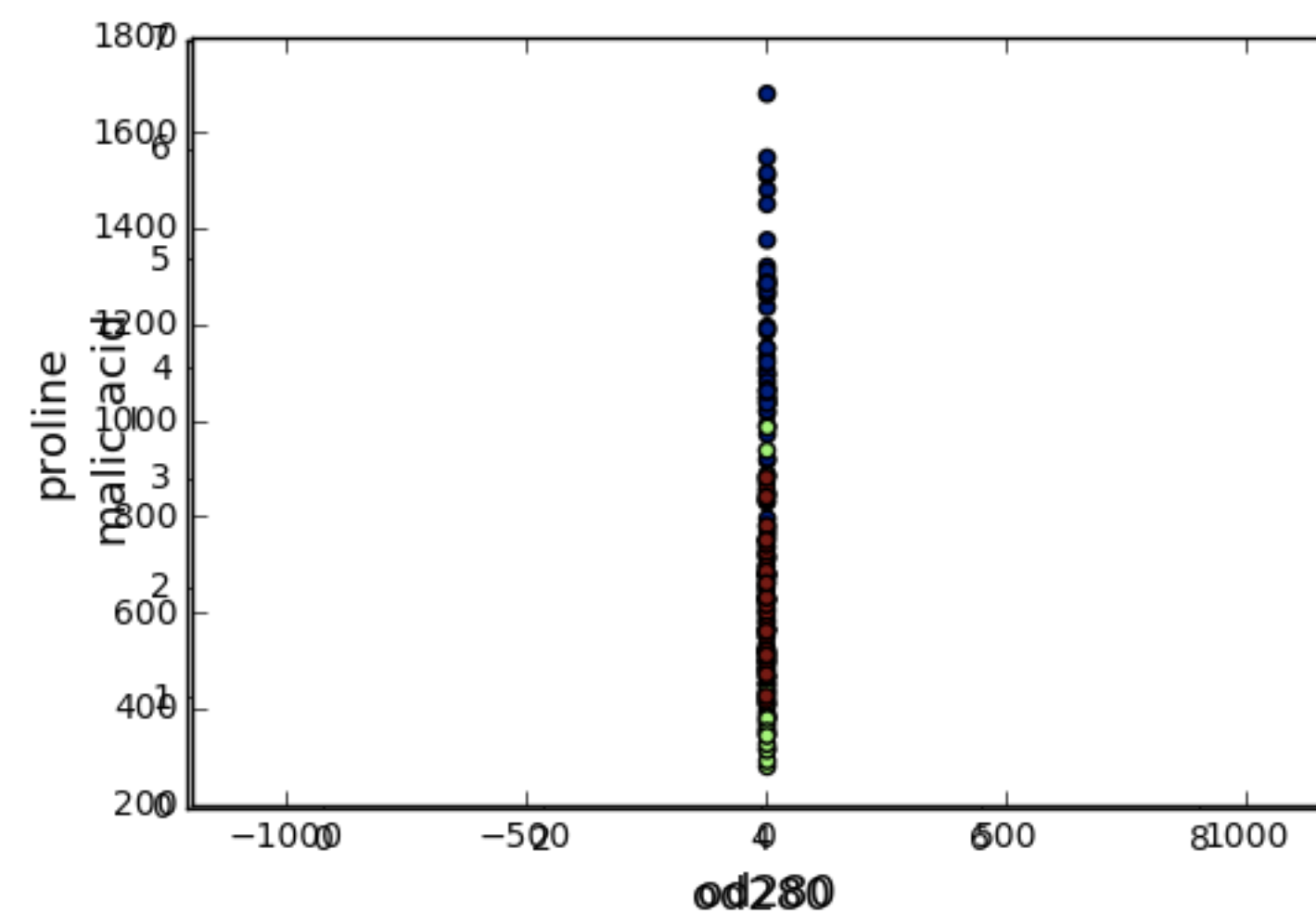
In [6]: print(ct)
varieties  Barbera  Barolo  Grignolino
labels
0           29      13      20
1           0      46       1
2          19       0      50
```



Feature variances

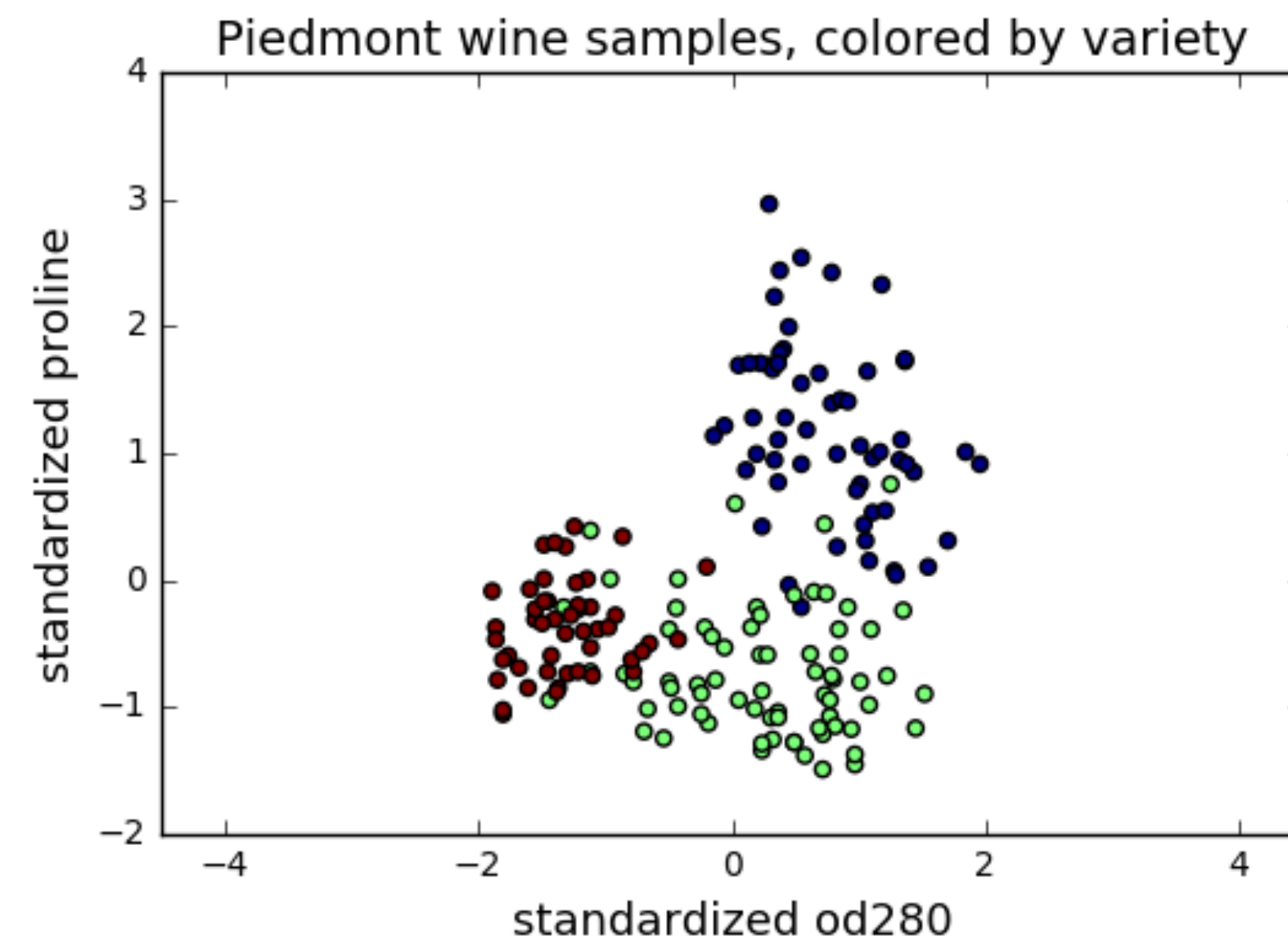
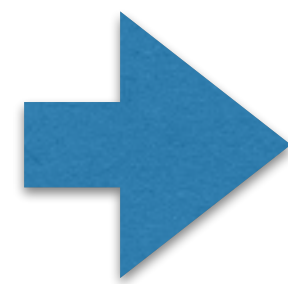
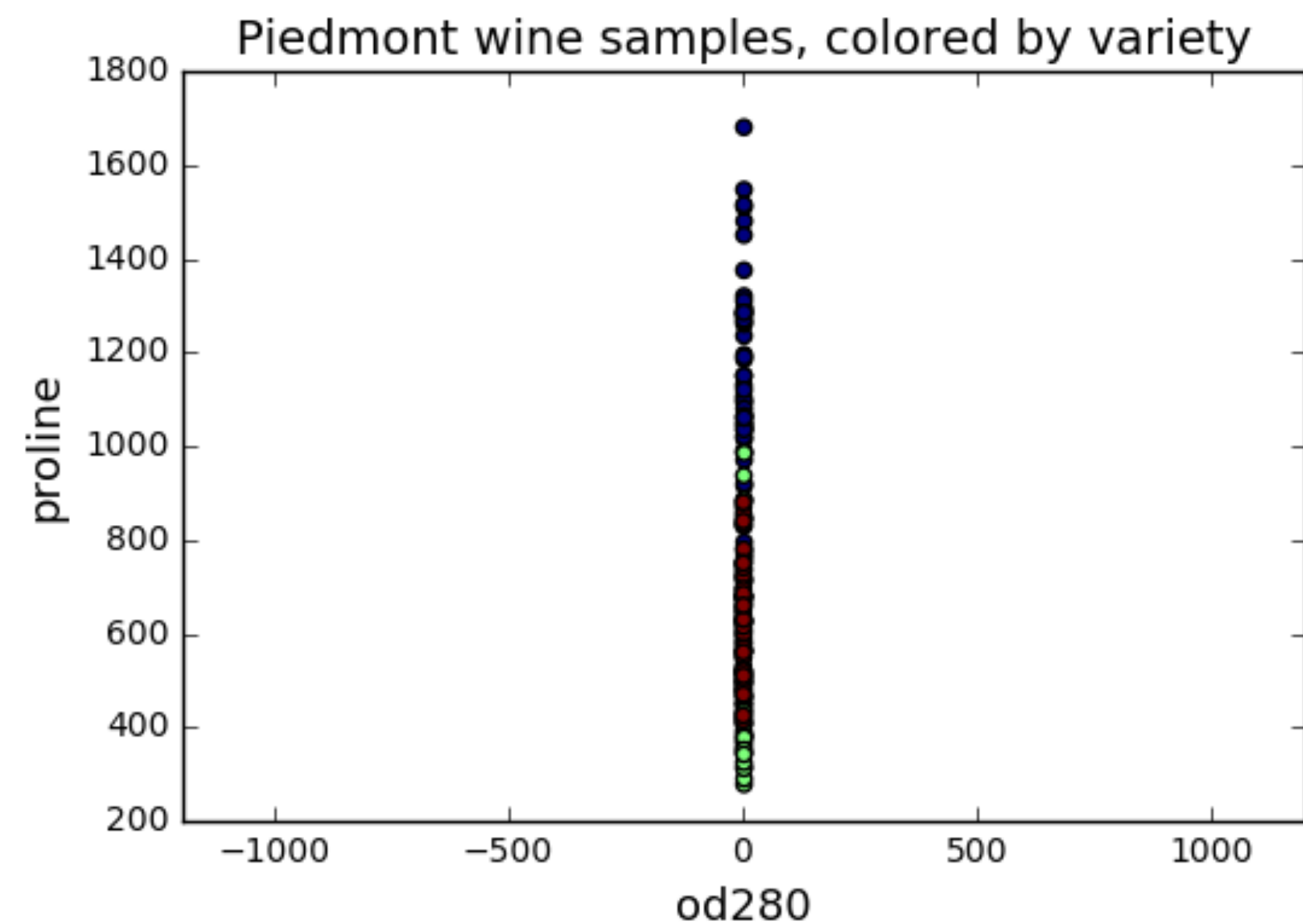
- The wine features have very different variances!
- Variance of a feature measures spread of its values

feature	variance
alcohol	0.65
malic_acid	1.24
...	
od280	0.50
proline	99166.71



StandardScaler

- In kmeans: feature variance = feature influence
- **StandardScaler** transforms each feature to have mean 0 and variance 1
- Features are said to be "standardized"





sklearn StandardScaler

```
In [1]: from sklearn.preprocessing import StandardScaler
```

```
In [2]: scaler = StandardScaler()
```

```
In [3]: scaler.fit(samples)
```

```
Out[3]: StandardScaler(copy=True, with_mean=True, with_std=True)
```

```
In [4]: samples_scaled = scaler.transform(samples)
```



Similar methods

- **StandardScaler** and **KMeans** have similar methods
- Use **fit()** / **transform()** with **StandardScaler**
- Use **fit()** / **predict()** with **KMeans**

StandardScaler, then KMeans

- Need to perform two steps: **StandardScaler**, then **KMeans**
- Use sklearn pipeline to combine multiple steps
- Data flows from one step into the next



Pipelines combine multiple steps

```
In [1]: from sklearn.preprocessing import StandardScaler
```

```
In [2]: from sklearn.cluster import KMeans
```

```
In [3]: scaler = StandardScaler()
```

```
In [4]: kmeans = KMeans(n_clusters=3)
```

```
In [5]: from sklearn.pipeline import make_pipeline
```

```
In [6]: pipeline = make_pipeline(scaler, kmeans)
```

```
In [7]: pipeline.fit(samples)
```

```
Out[7]: Pipeline(steps=...)
```

```
In [8]: labels = pipeline.predict(samples)
```



Feature standardization improves clustering

```
In [9]: df = pd.DataFrame({'labels': labels, 'varieties': varieties})
```

```
In [10]: ct = pd.crosstab(df['labels'], df['varieties'])
```

```
In [11]: print(ct)
```

varieties	Barbera	Barolo	Grignolino
0	0	59	3
1	48	0	3
2	0	0	65

***Without* feature standardization was very bad:**

varieties	Barbera	Barolo	Grignolino
0	29	13	20
1	0	46	1
2	19	0	50

sklearn preprocessing steps

- `StandardScaler` is a "preprocessing" step
- `MaxAbsScaler` and `Normalizer` are other examples



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