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# Class: Machine Learning

# Machine Learning Evaluation

**Instructor: Matteo Leonetti**

# Learning outcomes

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- Define *overfitting*.
- Apply a strategy to avoid overfitting.
- List the main accuracy metrics to measure the performance of a classifier.
- Choose the appropriate metric for a given classification problem.
- Apply the metrics to real data sets and classifiers.

# Feature Selection

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The first step before any classification can take place is to decide what *features* we are considering when trying to discriminate two sets.

For example, we could use width and height, or colour, shape…

# Two possible solutions

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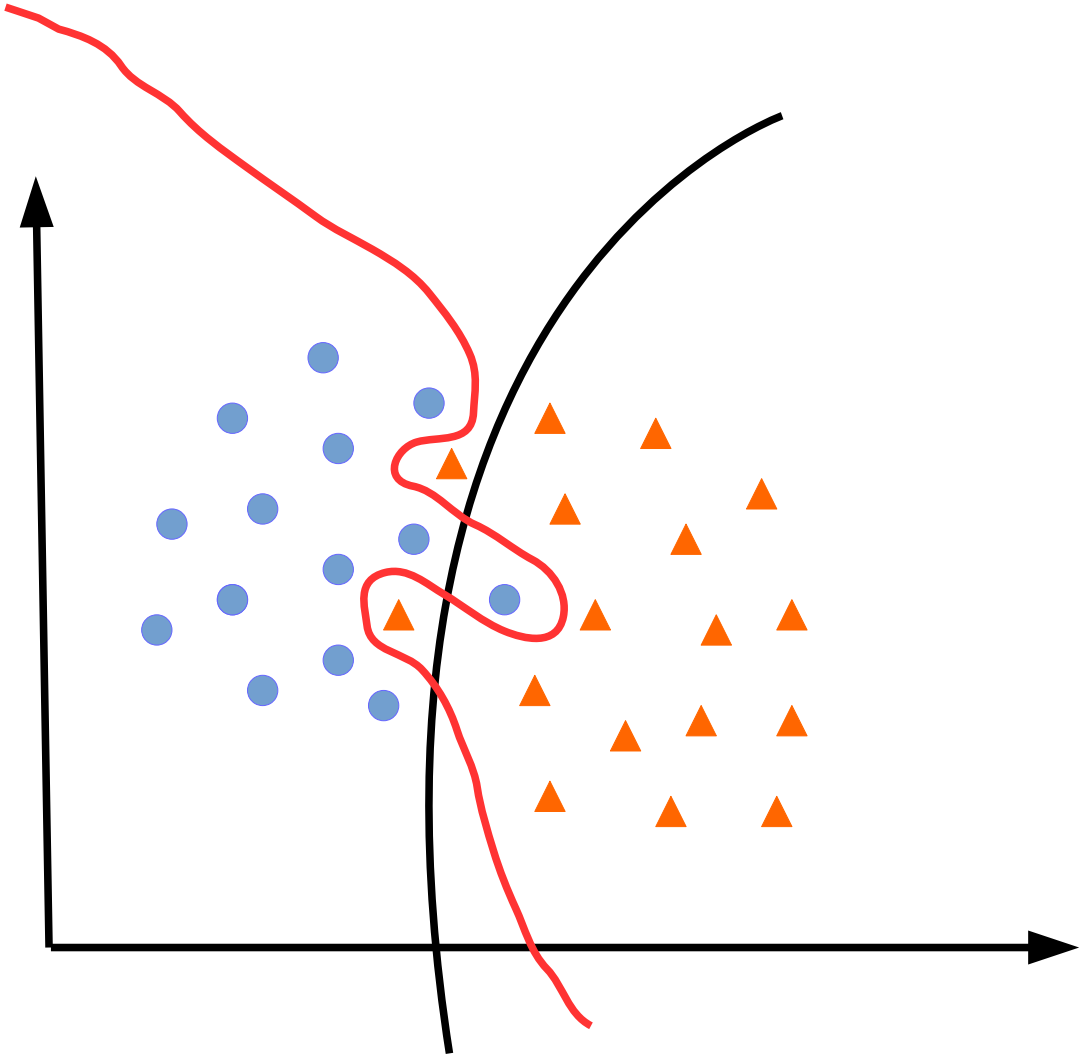

Which one would you say it's best?

# Overfitting

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A model *overfits* when it describes the randomness associated with the data, rather than the underlying relationship between the data points.

# Occam's razor

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Attributed to William of Ockham (~1300 A.D.):

Entities should not be multiplied unnecessarily

# Preventing Overfitting

# Test set

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Training data Test data

Test on a portion of the data different from training.

# Example: parametric classifier

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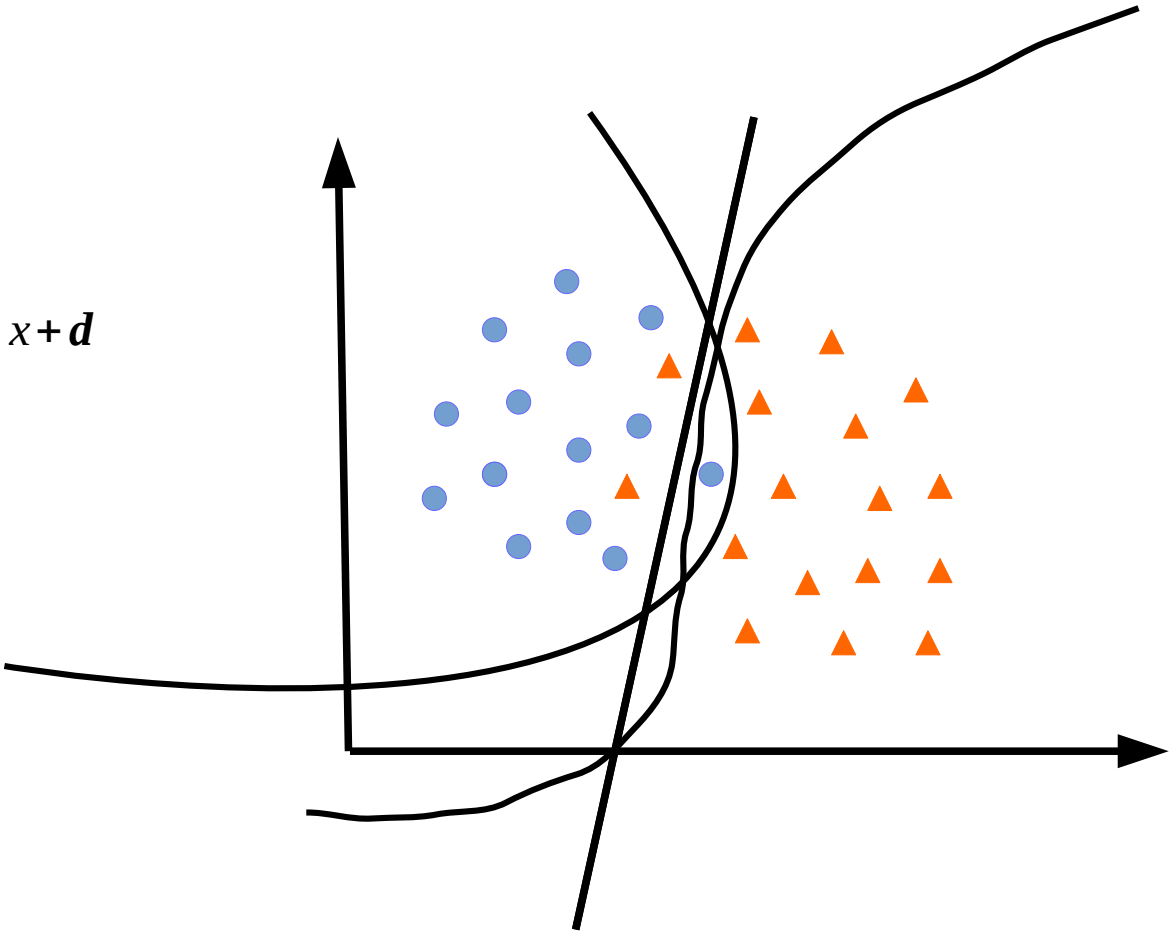
You may want to choose between different models, for instance:

Different orders of polynomials:

$$y = \boldsymbol{a}\, x + \boldsymbol{b}$$

$$y = \boldsymbol{a}\, x^2 + \boldsymbol{b}\, x + \boldsymbol{c}$$

$$y = \boldsymbol{a}\, x^3 + \boldsymbol{b}\, x^2 + \boldsymbol{c}\, x + \boldsymbol{d}$$



# Validation set

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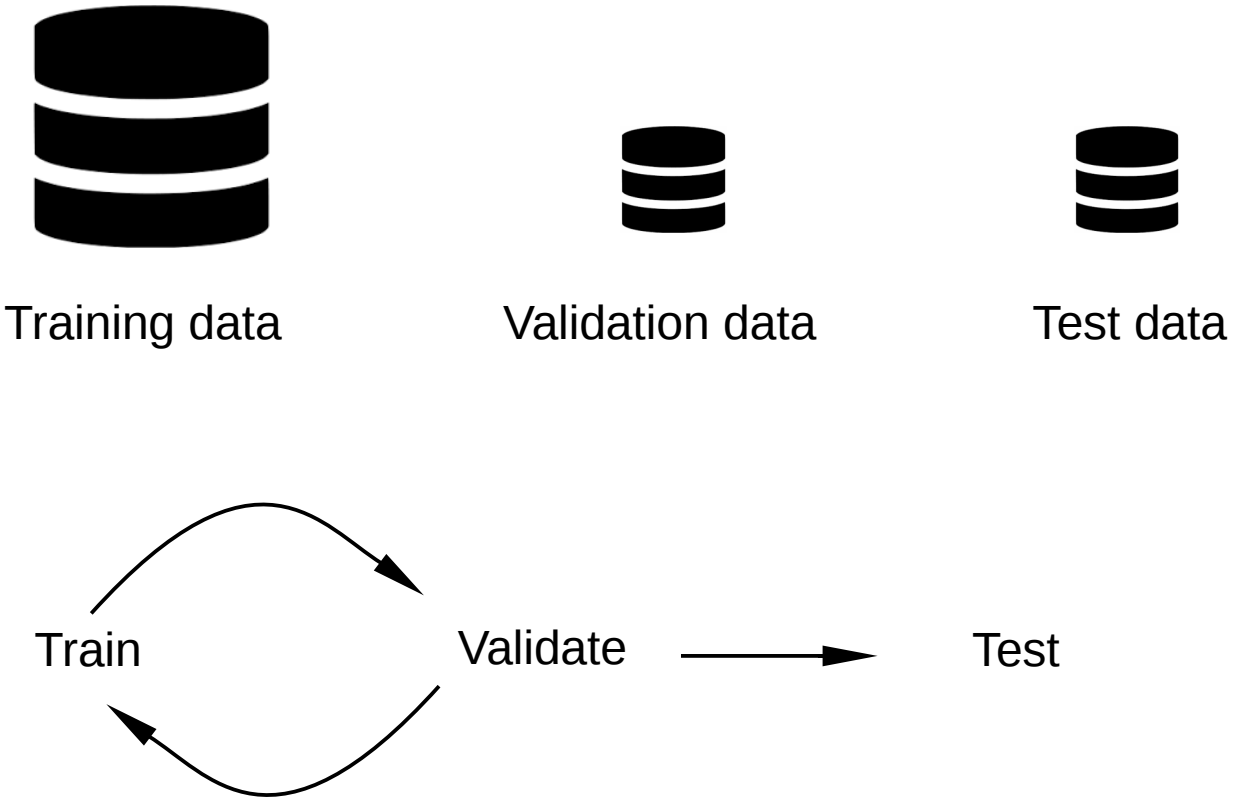

# When to stop learning

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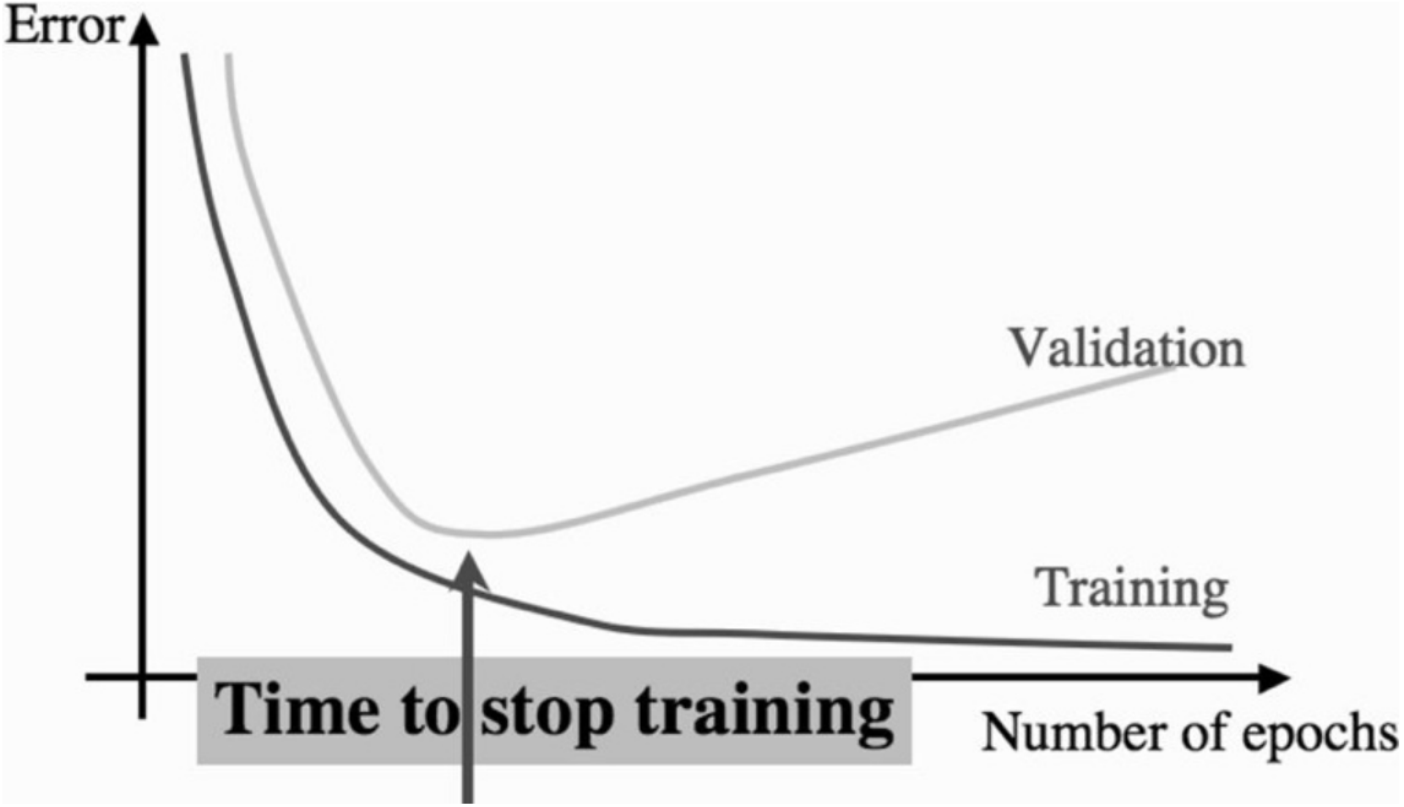

# Cross validation

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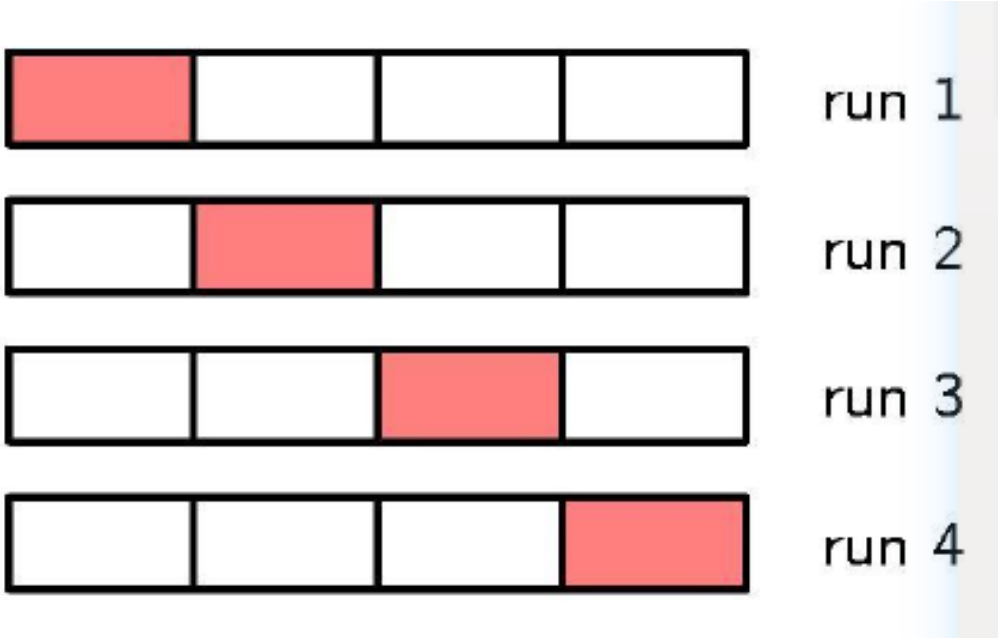

# Measuring Accuracy

# Accuracy on a binary classifier

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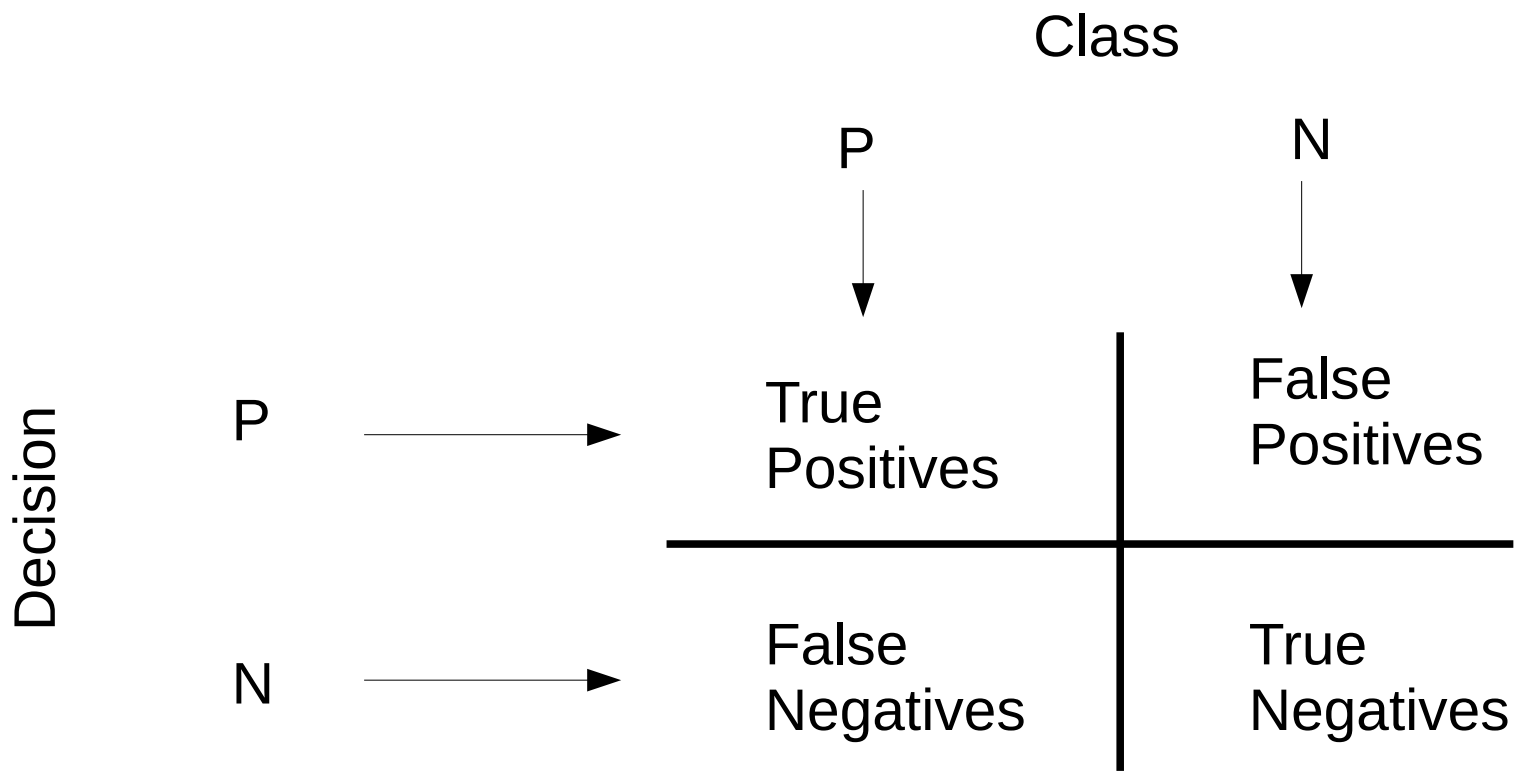

# Accuracy on a binary classifier

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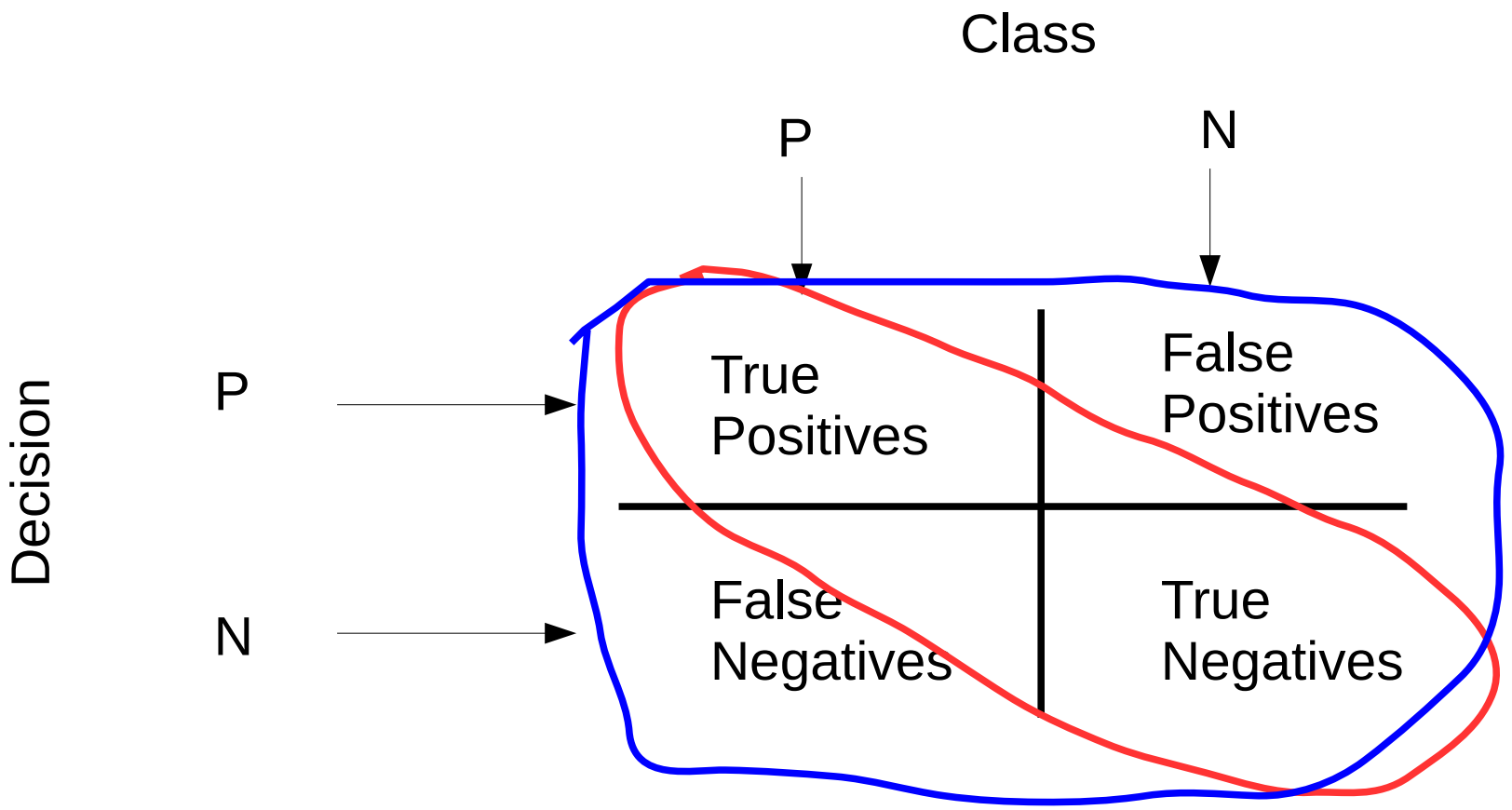


Accuracy

# Accuracy on a binary classifier

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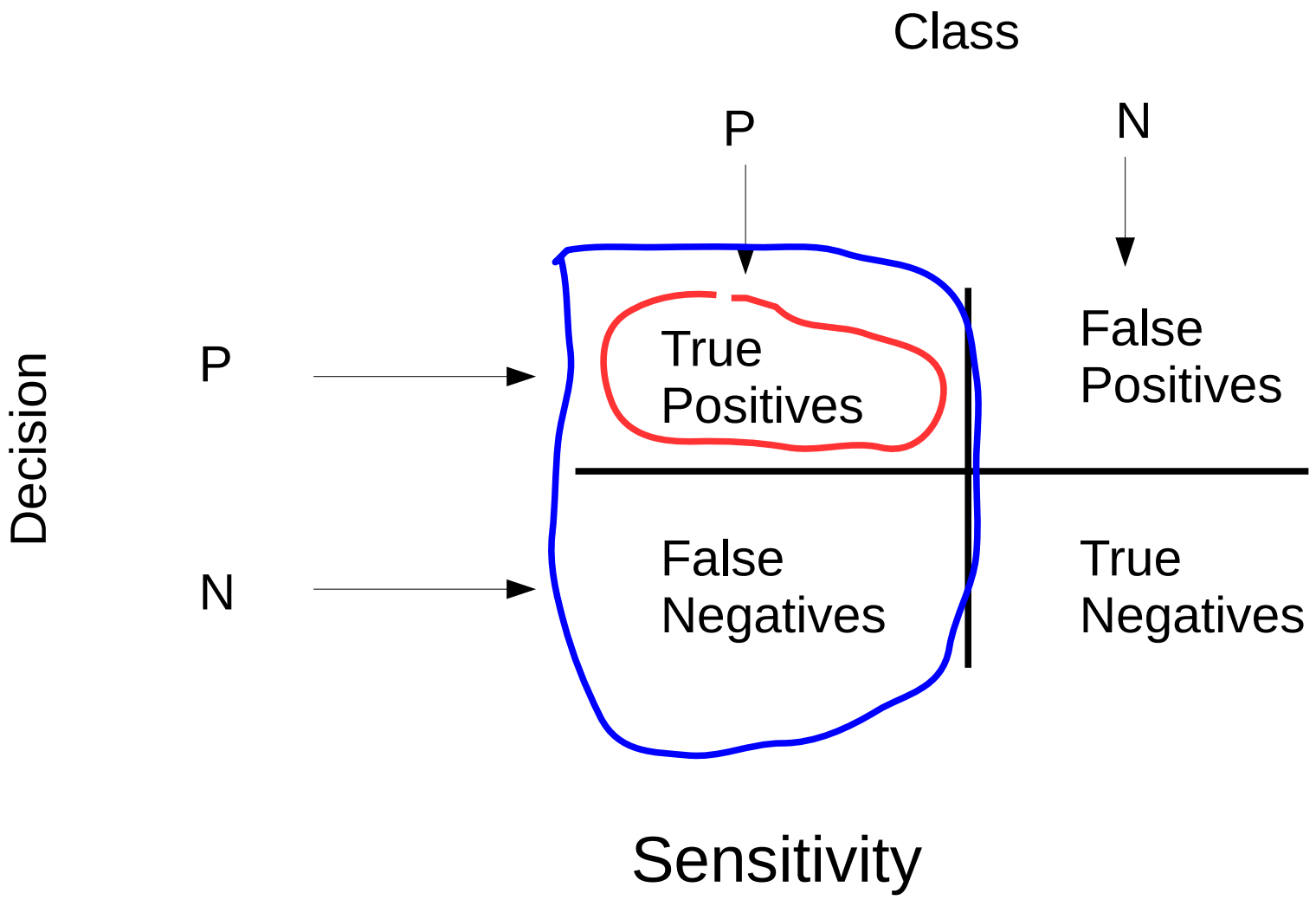

# Accuracy on a binary classifier

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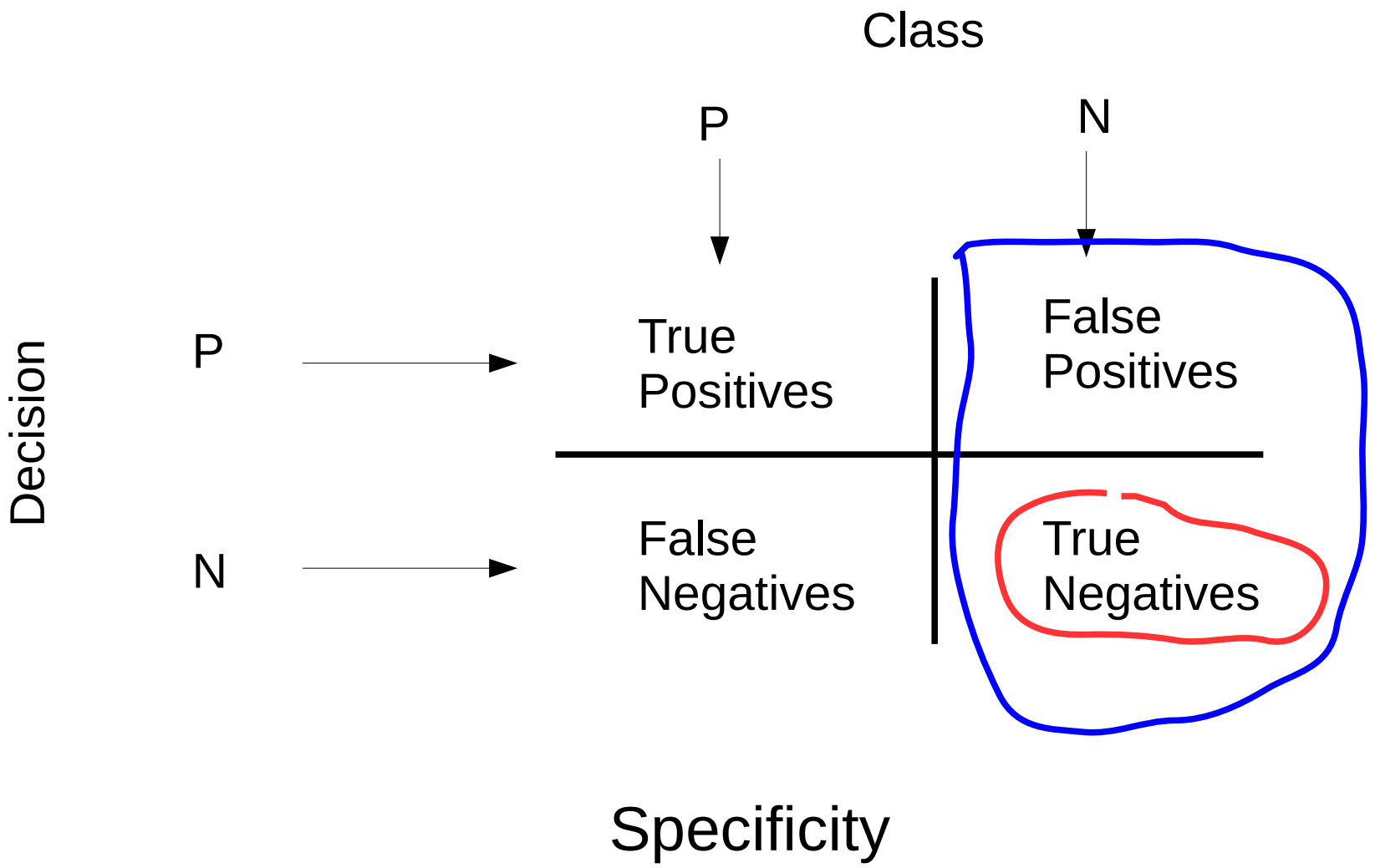

# Accuracy on a binary classifier

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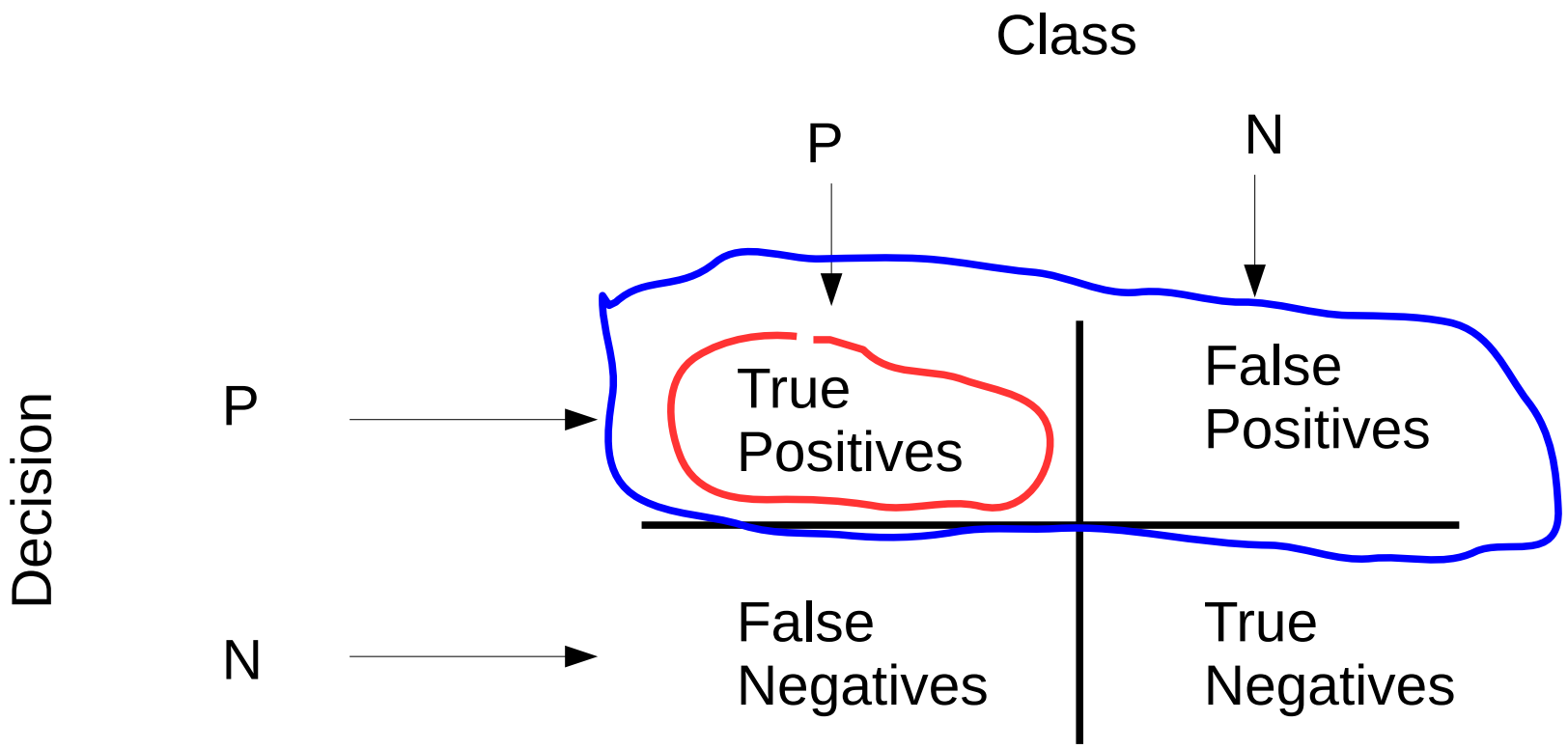


Precision

# Accuracy on a binary classifier

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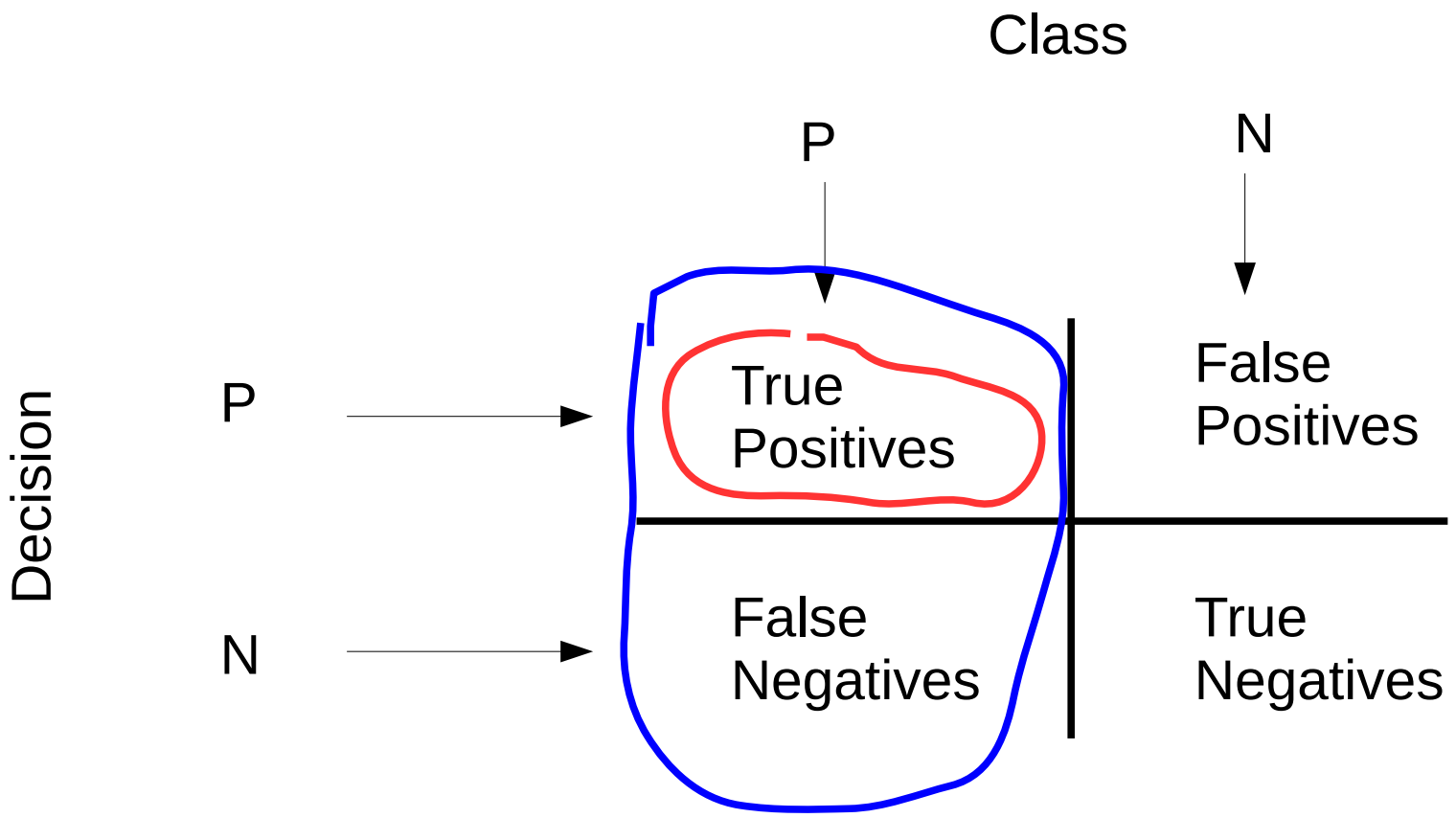


Recall (same as sensitivity)

# Accuracy metrics

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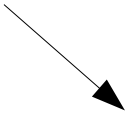
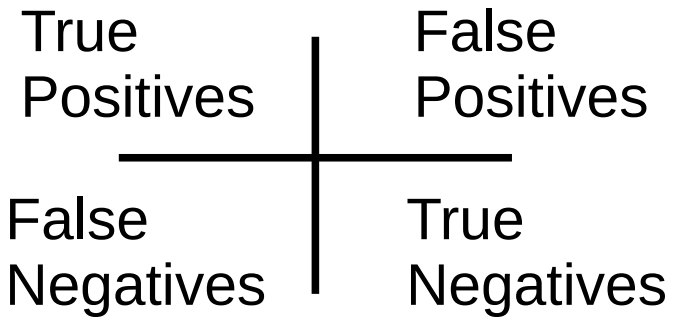
TN!



$$\text{Accuracy} = \frac{\#TP + \#FP}{\#TP + \#FP + \#TN + \#FN}.$$




$$\text{Sensitivity} = \frac{\#TP}{\#TP + \#FN}$$

$$\text{Specificity} = \frac{\#TN}{\#TN + \#FP}$$

$$\text{Precision} = \frac{\#TP}{\#TP + \#FP}$$

$$\text{Recall} = \frac{\#TP}{\#TP + \#FN}$$

$$F_1 = 2\frac{\text{precision} \times \text{recall}}{\text{precision} + \text{recall}} \qquad 0 \leqslant F_1 \leqslant 1$$

$$MCC = \frac{\#TP \times \#TN - \#FP \times \#FN}{\sqrt{(\#TP + \#FP)(\#TP + \#FN)(\#TN + \#FP)(\#TN + \#FN)}}$$

$$-1 \leqslant MCC \leqslant 1$$

# Confusion Matrix

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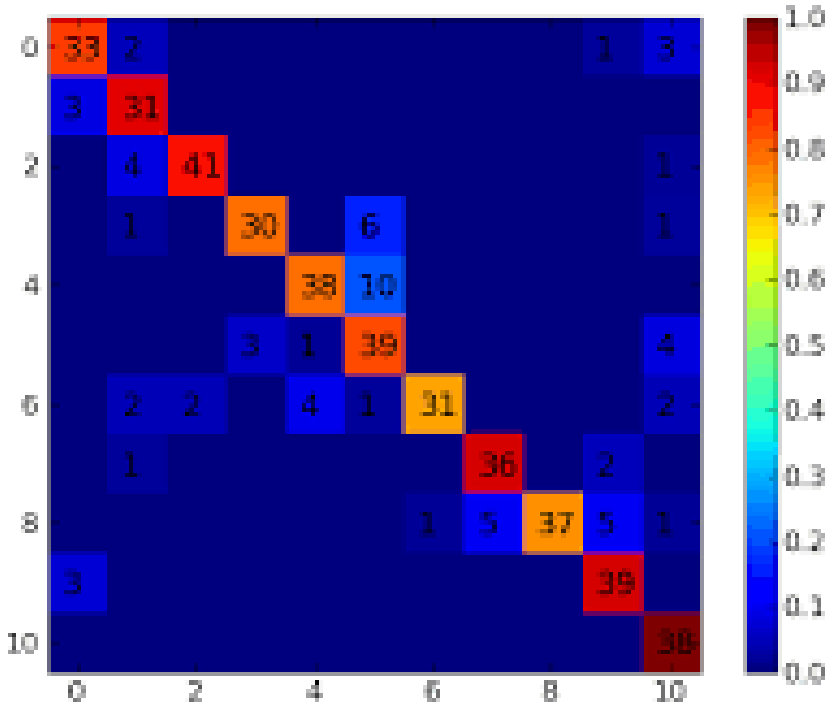

# ROC curve

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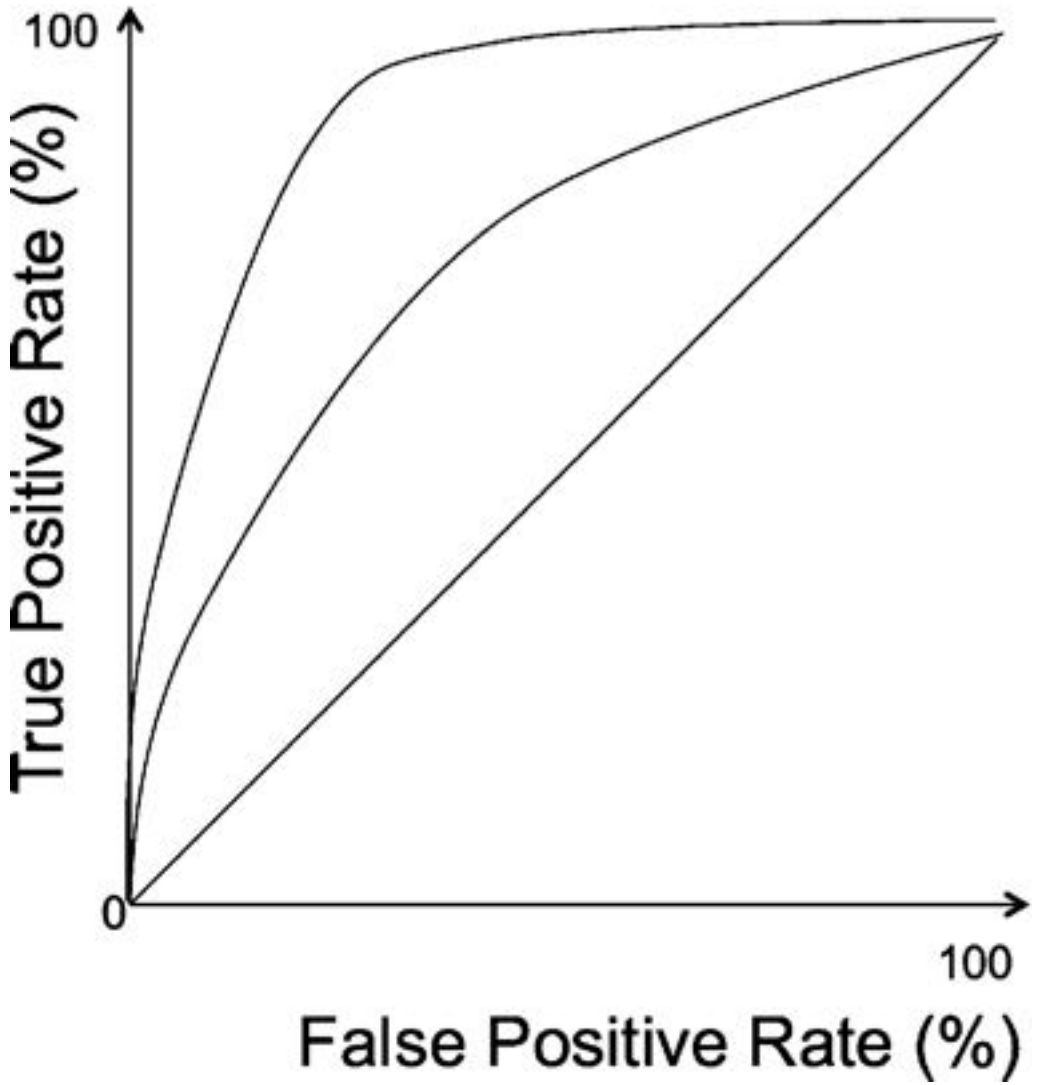

# Conclusion

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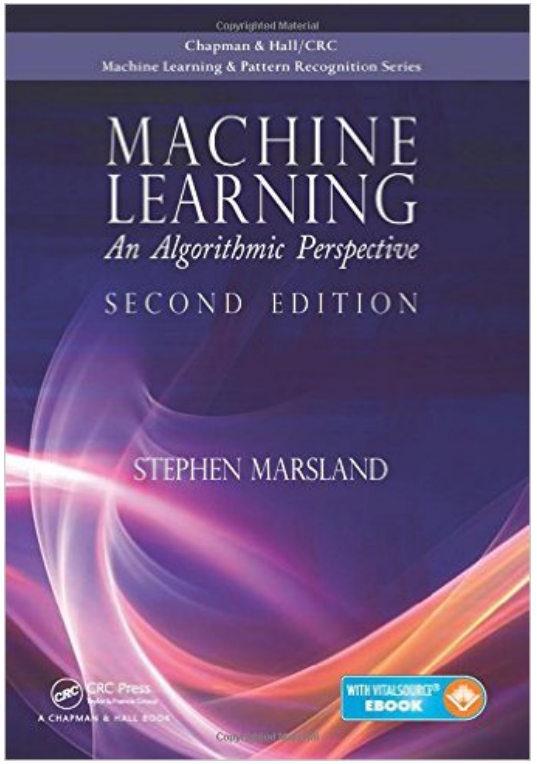


# Chapter 2, up to 2.2