CS 484
Data Mining

Classification

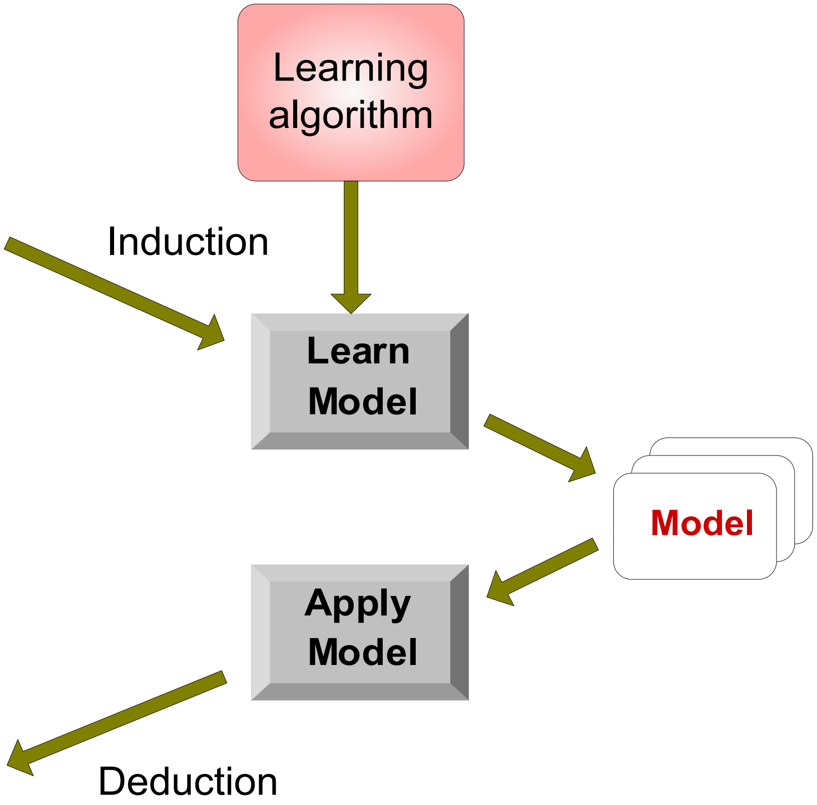
Classification: Definition

- Given a collection of records (*training set*)
  - Each record contains a set of *attributes*, one of the attributes is the *class*.
- Find a *model* for class attribute as a function of the values of other attributes.
- Goal: previously unseen records should be assigned a class as accurately as possible.
  - A *test set* is used to determine the accuracy of the model. Usually, the given data set is divided into training and test sets, with training set used to build the model and test set used to validate it.

Illustrating Classification Task

Tid	Attrib1	Attrib2	Attrib3	Class
1	Yes	Large	125K	No
2	No	Medium	100K	No
3	No	Small	70K	No
4	Yes	Medium	120K	No
5	No	Large	95K	Yes
6	No	Medium	60K	No
7	Yes	Large	220K	No
8	No	Small	85K	Yes
9	No	Medium	75K	No
10	No	Small	90K	Yes

Training Set



Tid	Attrib1	Attrib2	Attrib3	Class
11	No	Small	55K	?
12	Yes	Medium	80K	?
13	Yes	Large	110K	?
14	No	Small	95K	?
15	No	Large	67K	?

Test Set

Examples of Classification Task

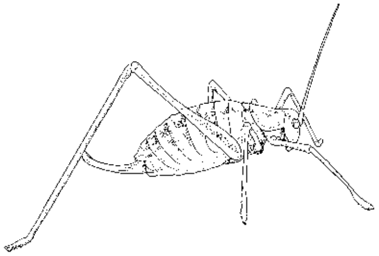
- Predicting tumor cells as benign or malignant

- Classifying credit card transactions as legitimate or fraudulent

- Categorizing news stories as finance, weather, entertainment, sports, etc

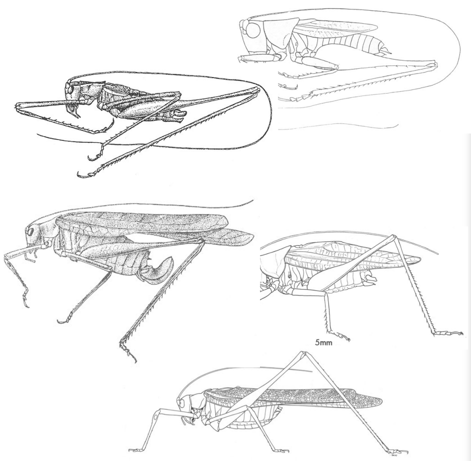
The Classification Problem
(informal definition)

Given a collection of annotated data. In this case 5 instances of **Katydids** and five of **Grasshoppers**, decide what type of insect the unlabeled example is.

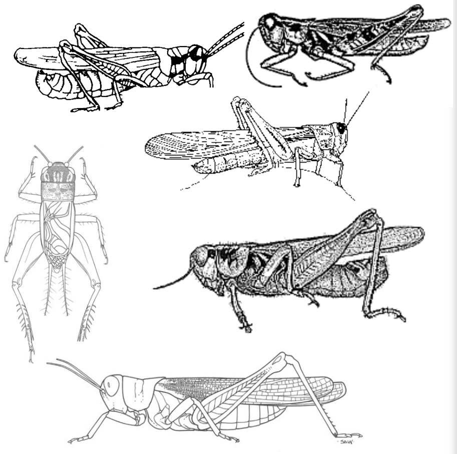


Katydid or Grasshopper?

Katydids



Grasshoppers



For any domain of interest, we can measure *features*

Color {Green, Brown, Gray, Other}

Has Wings?

Abdomen Length

Thorax Length

Antennae Length

.

Mandible Size

Spiracle Diameter

Leg Length

We can store features in a database.

My_Collection

Insect ID	Abdomen Length	Antennae Length	Insect Class
1	2.7	5.5	Grasshopper
2	8.0	9.1	Katydid
3	0.9	4.7	Grasshopper
4	1.1	3.1	Grasshopper
5	5.4	8.5	Katydid
6	2.9	1.9	Grasshopper
7	6.1	6.6	Katydid
8	0.5	1.0	Grasshopper
9	8.3	6.6	Katydid
10	8.1	4.7	Katydids

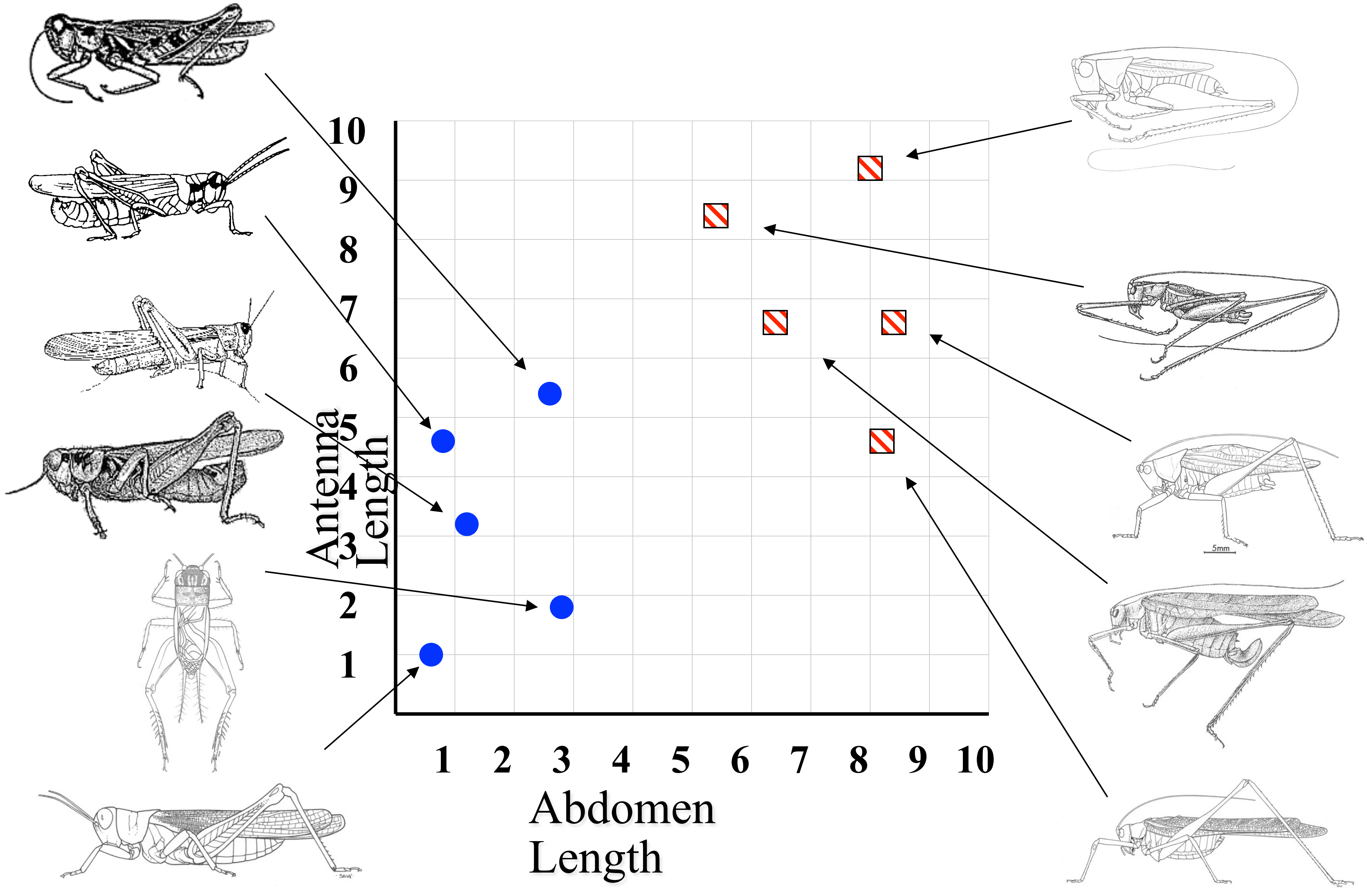
The classification problem can now be expressed as:

Given a training database (My_Collection), predict the class label of a previously unseen instance

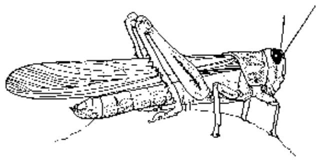
previously unseen instance =

11	5.1	7.0	??????

Grasshoppers **Katydids**

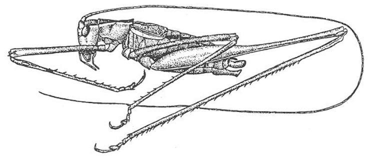


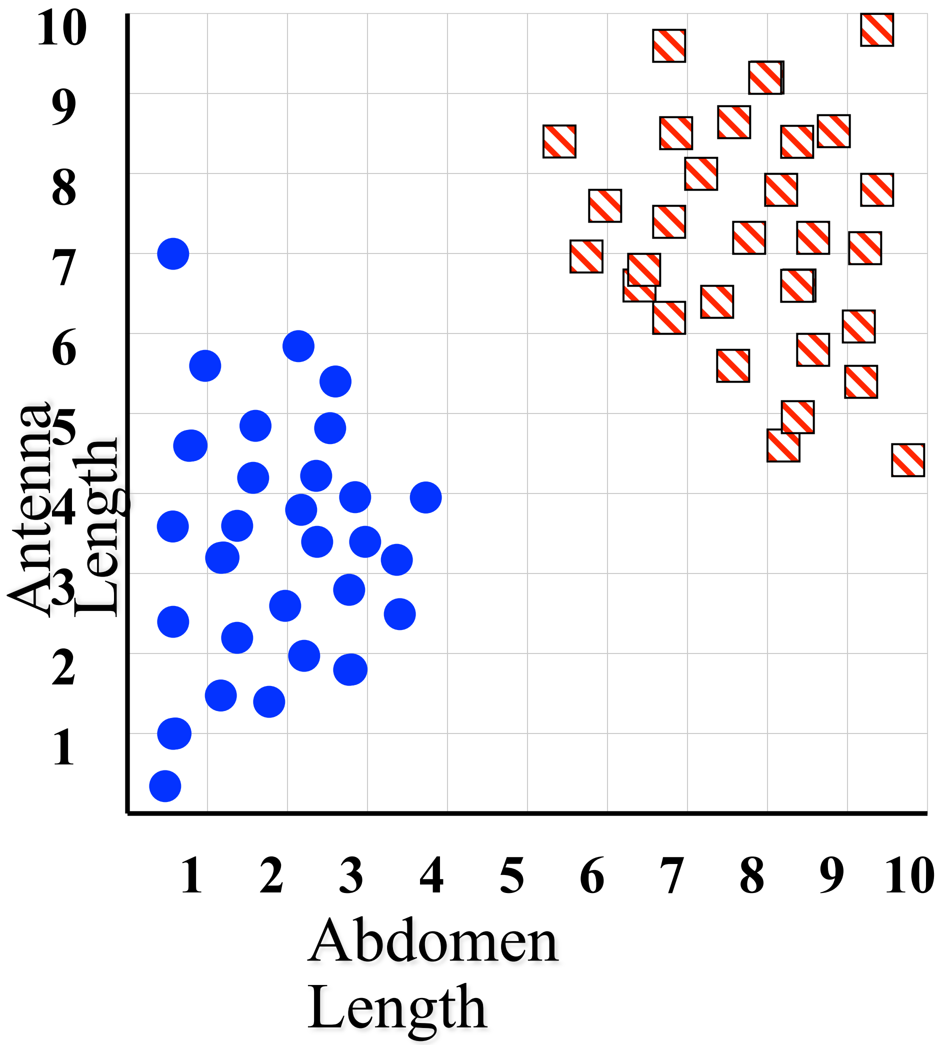
Grasshoppers



We will also use this lager dataset as a motivating example…

Katydids





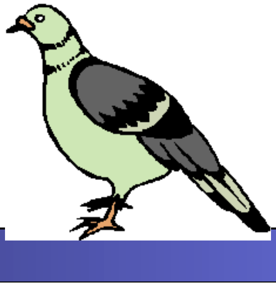
Each of these data objects are called…

- exemplars
- (training) examples
- instances
- tuples

We will return to the previous slide in two minutes. In the meantime, we are going to play a quick game.

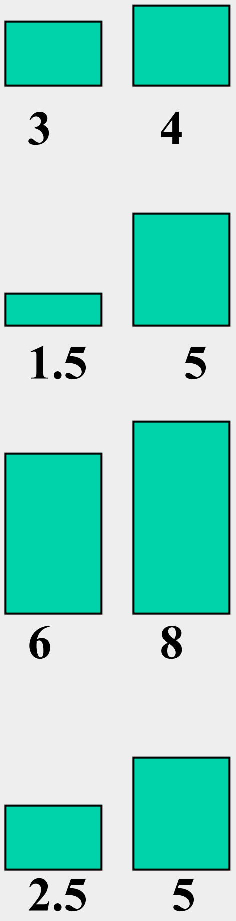
I am going to show you some classification problems which were shown to pigeons!

Let us see if you are as smart as a pigeon!

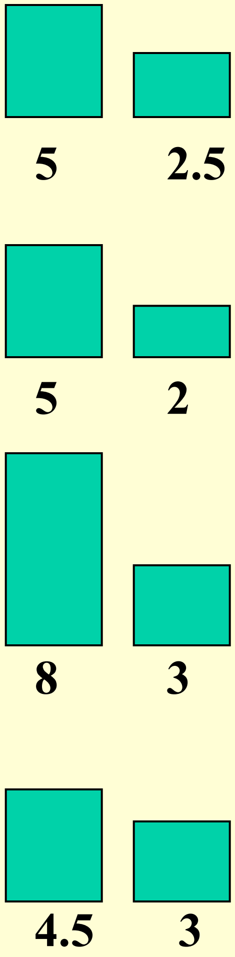


Pigeon Problem 1

Examples of class A

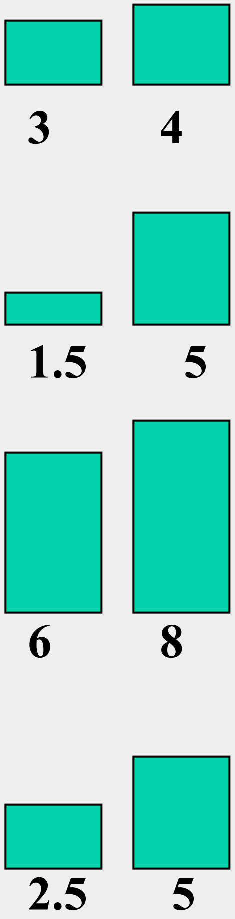


Examples of class B

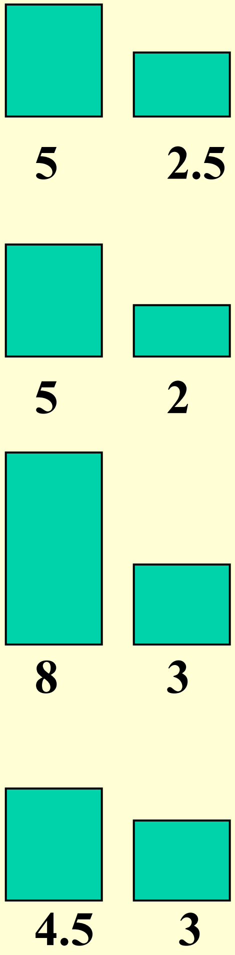


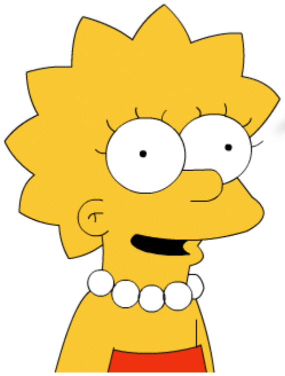
Pigeon Problem 1

Examples of class A

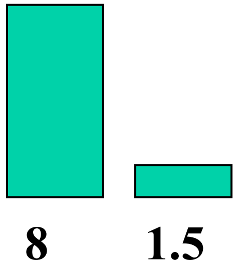


Examples of class B

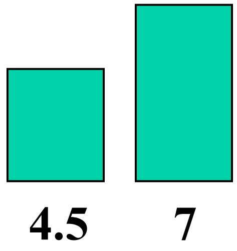




What class is this object?

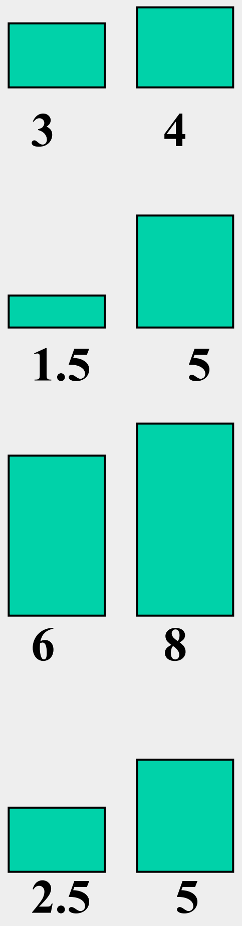


What about this one, A or B?

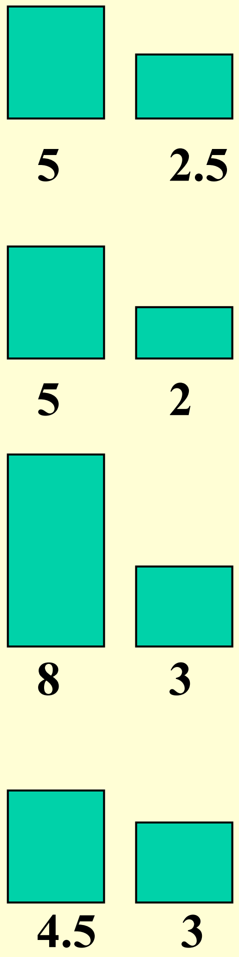


Pigeon Problem 1

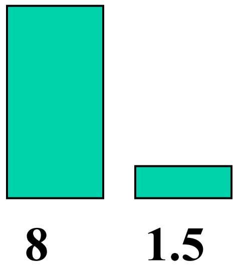
Examples of class A



Examples of class B



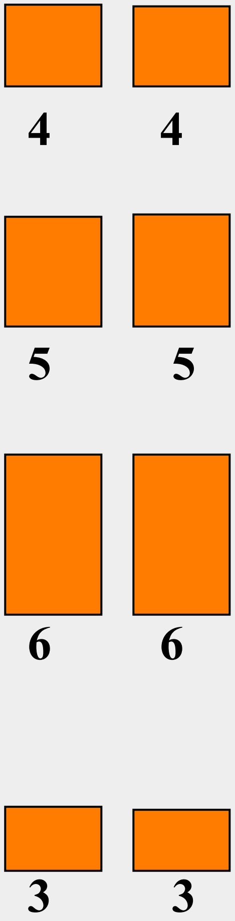
This is a B!



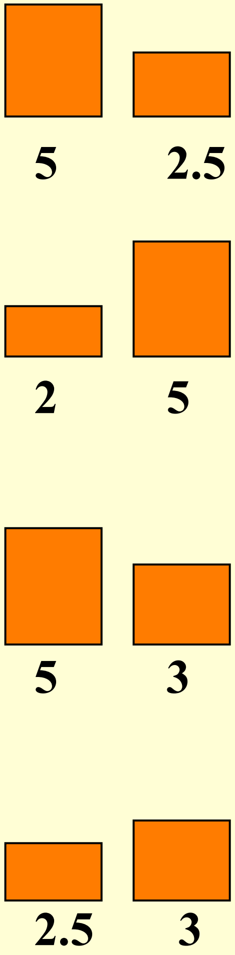
Here is the rule.
If the left bar is smaller than the right bar, it is an A, otherwise it is a B.

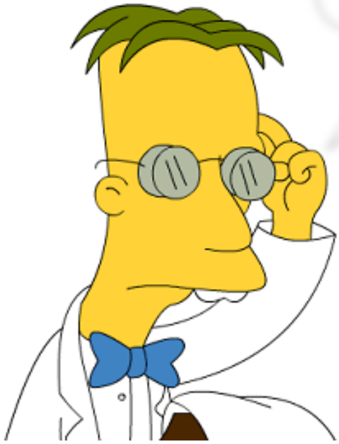
Pigeon Problem 2

Examples of class A

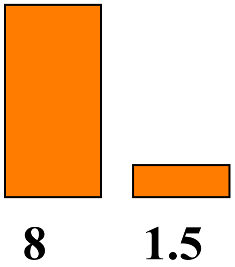


Examples of class B

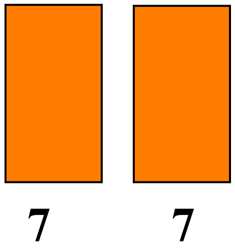




Oh! This ones hard!

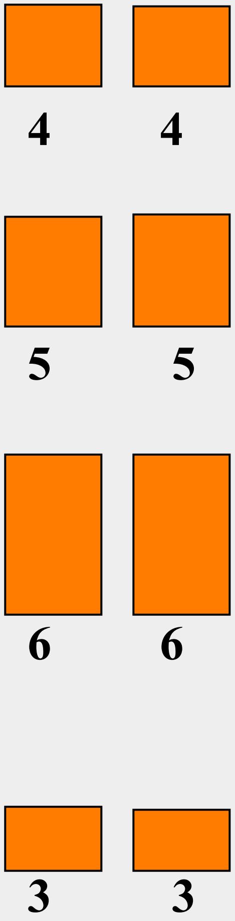


Even I know this one

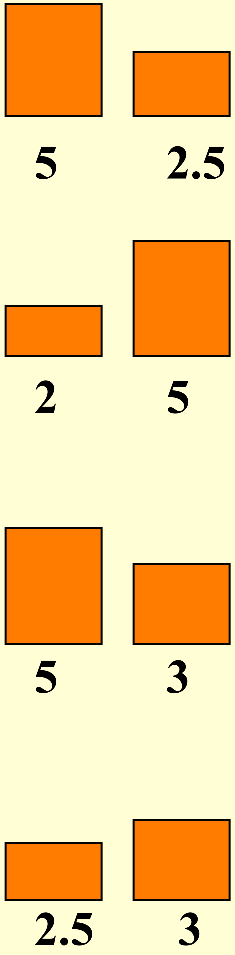


Pigeon Problem 2

Examples of class A

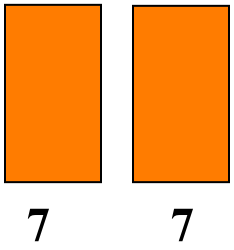


Examples of class B



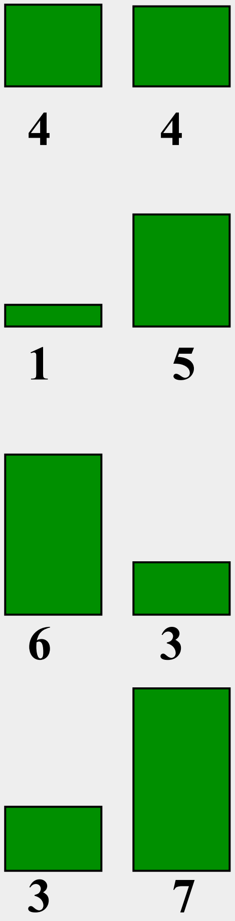
The rule is as follows, if the two bars are equal sizes, it is an A. Otherwise it is a B.

So this one is an A.

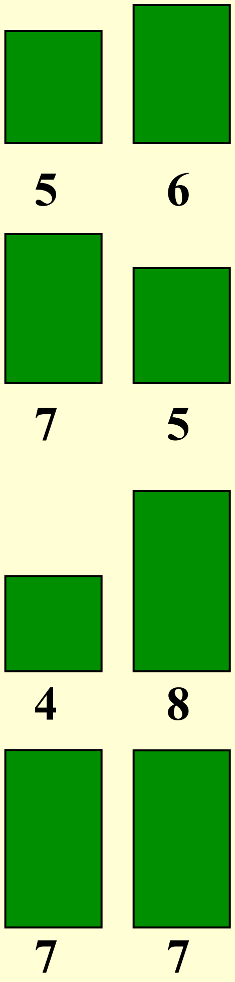


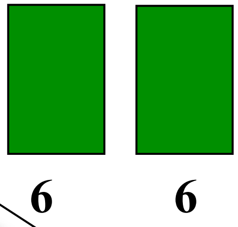
Pigeon Problem 3

Examples of class A



Examples of class B

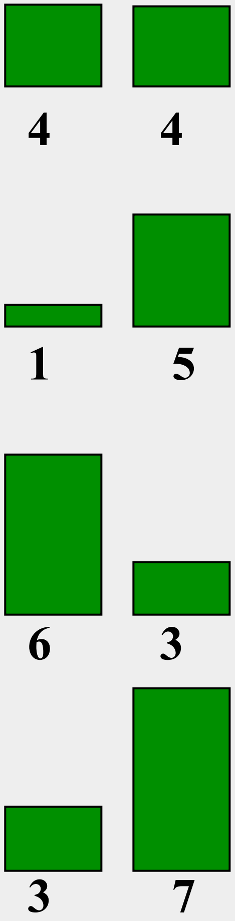




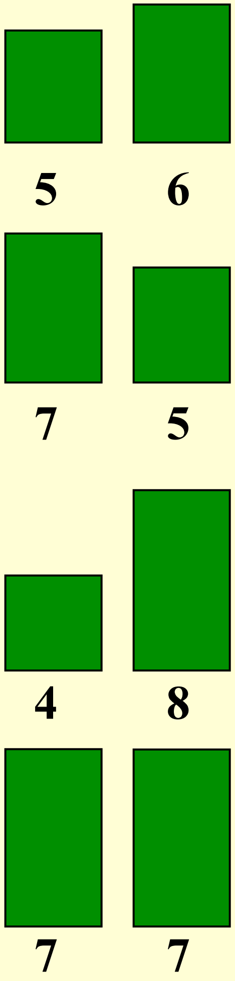
This one is really hard!
What is this, A or B?

Pigeon Problem 3

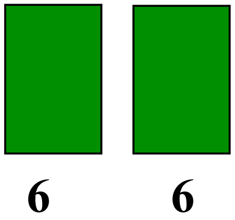
Examples of class A



Examples of class B



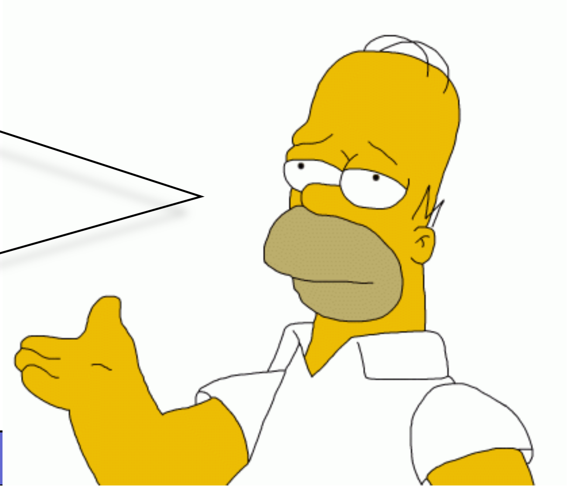
It is a B!



The rule is as follows, if the square of the sum of the two bars is less than or equal to 100, it is an A. Otherwise it is a B.

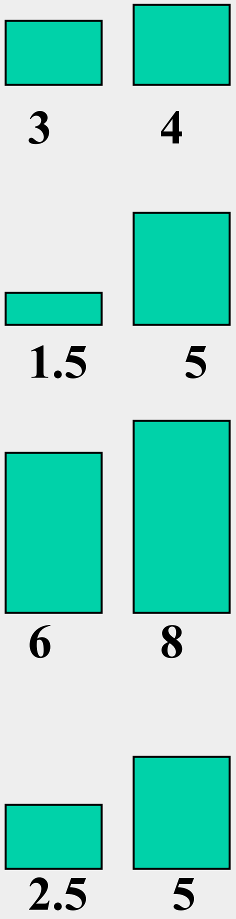
Why did we spend so much time with this game?

Because we wanted to show that almost all classification problems have a geometric interpretation, check out the next 3 slides…

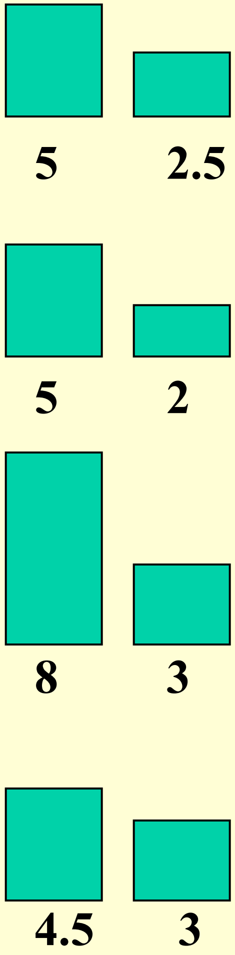


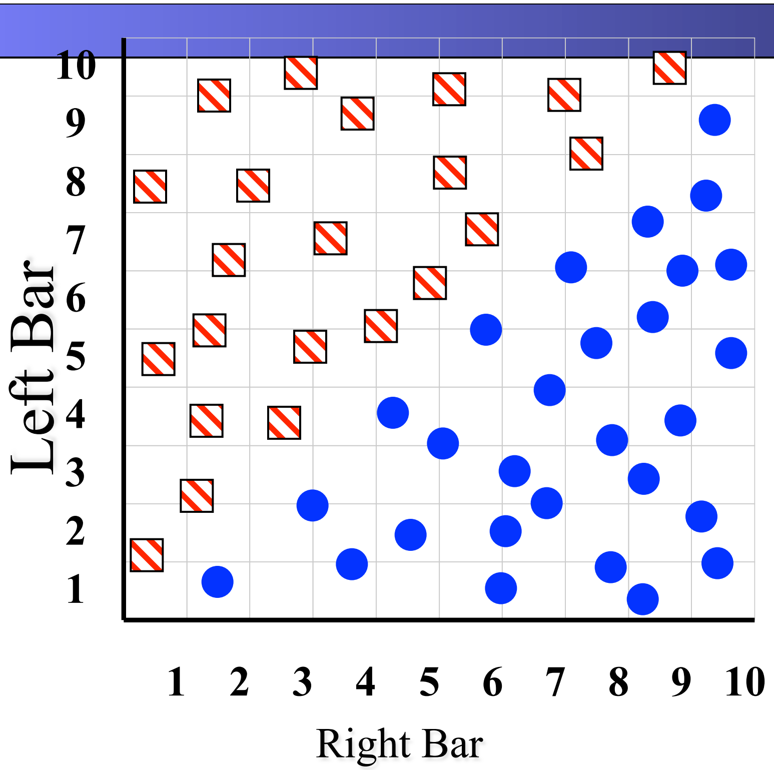
Pigeon Problem 1

Examples of class A



Examples of class B

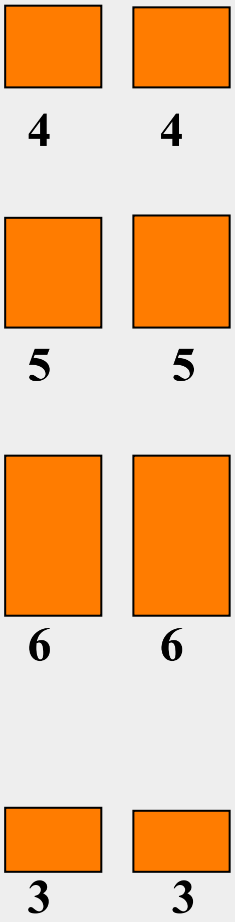




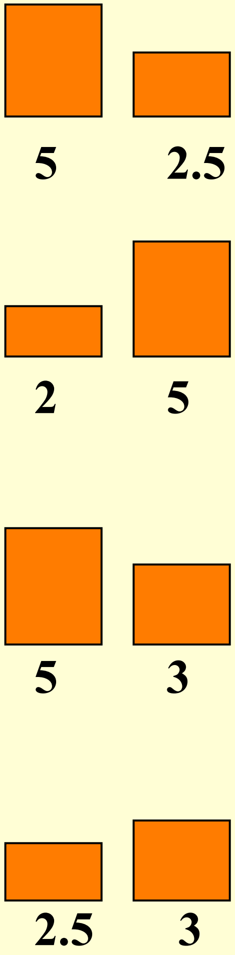
Here is the rule again.
If the left bar is smaller than the right bar, it is an A, otherwise it is a B.

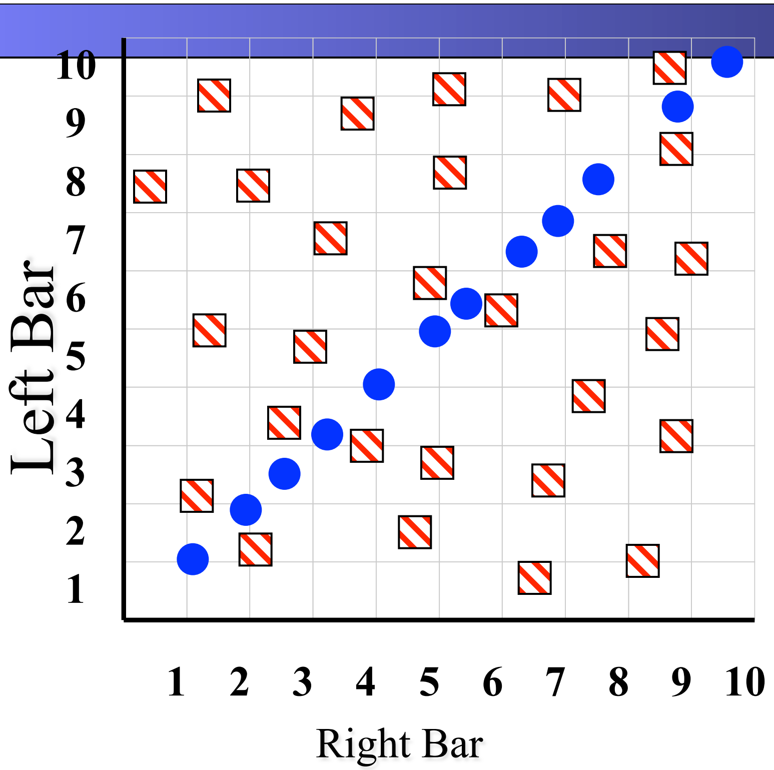
Pigeon Problem 2

Examples of class A



Examples of class B

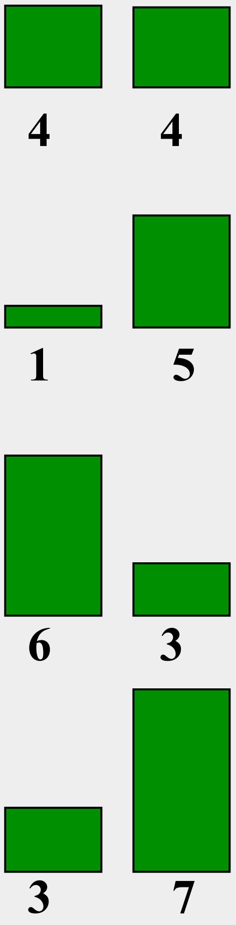




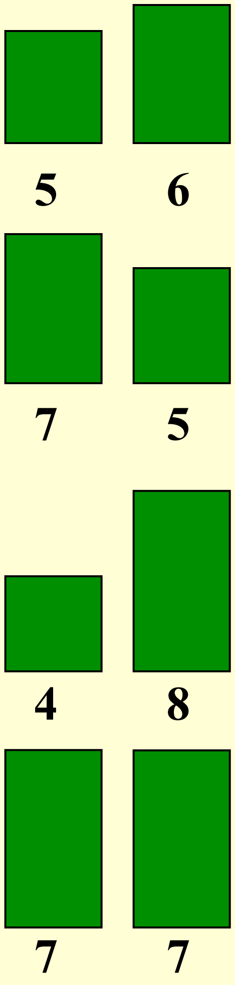
Let me look it up… here it is.. the rule is, if the two bars are equal sizes, it is an A. Otherwise it is a B.

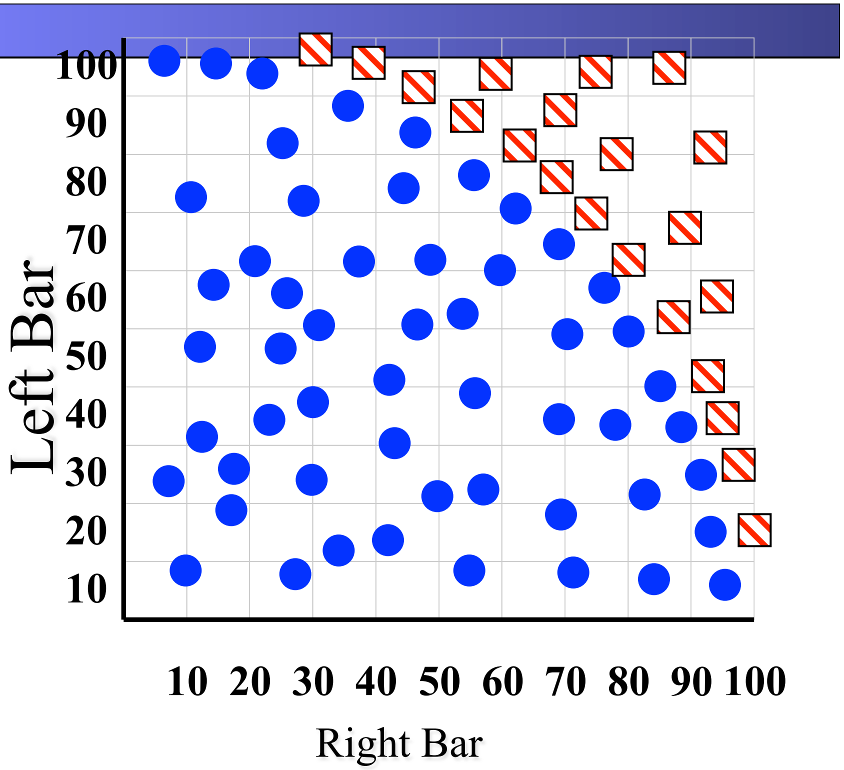
Pigeon Problem 3

Examples of class A



Examples of class B

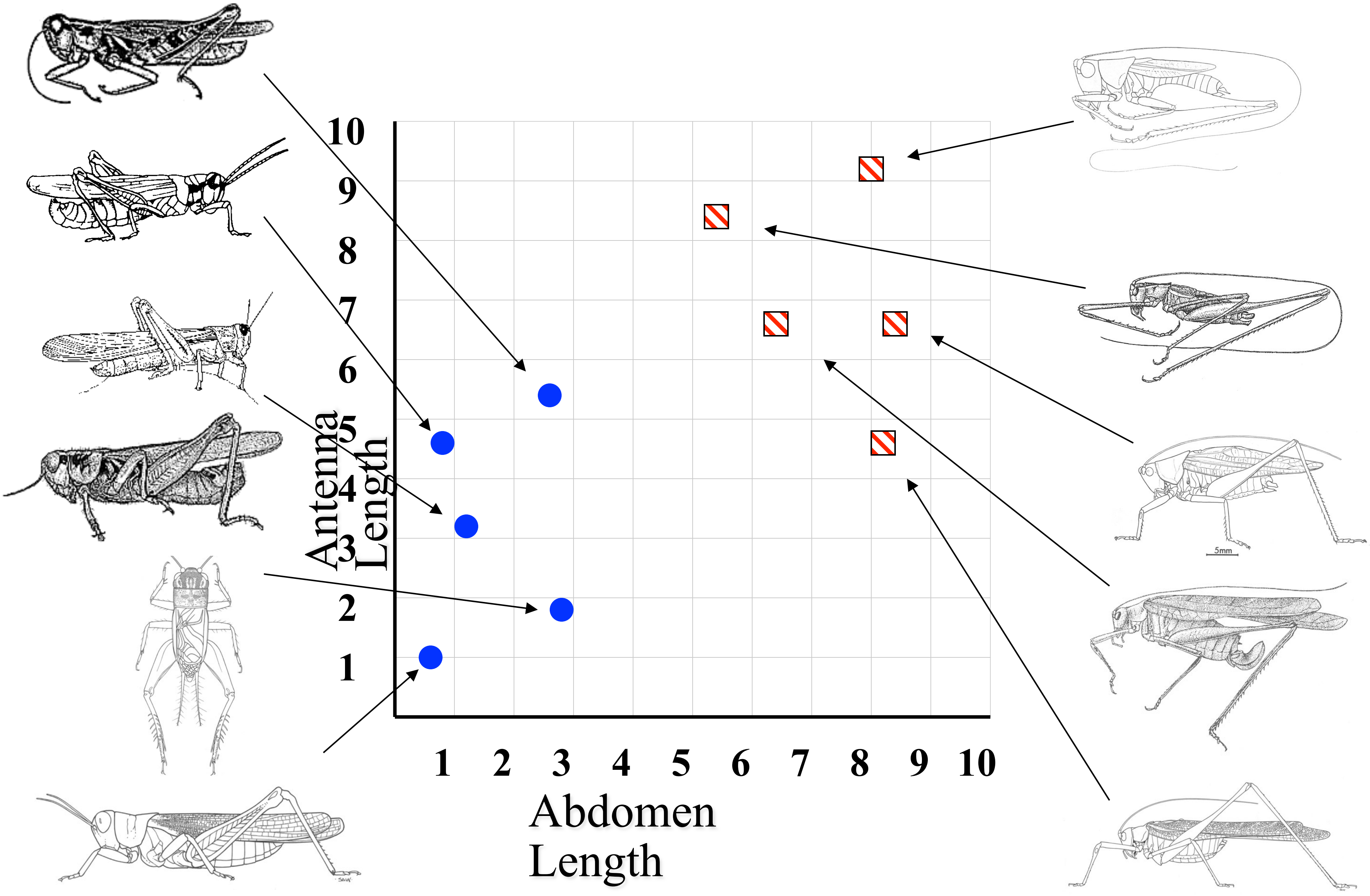




The rule again:
if the square of the sum of the two bars is less than or equal to 100, it is an A. Otherwise it is a B.

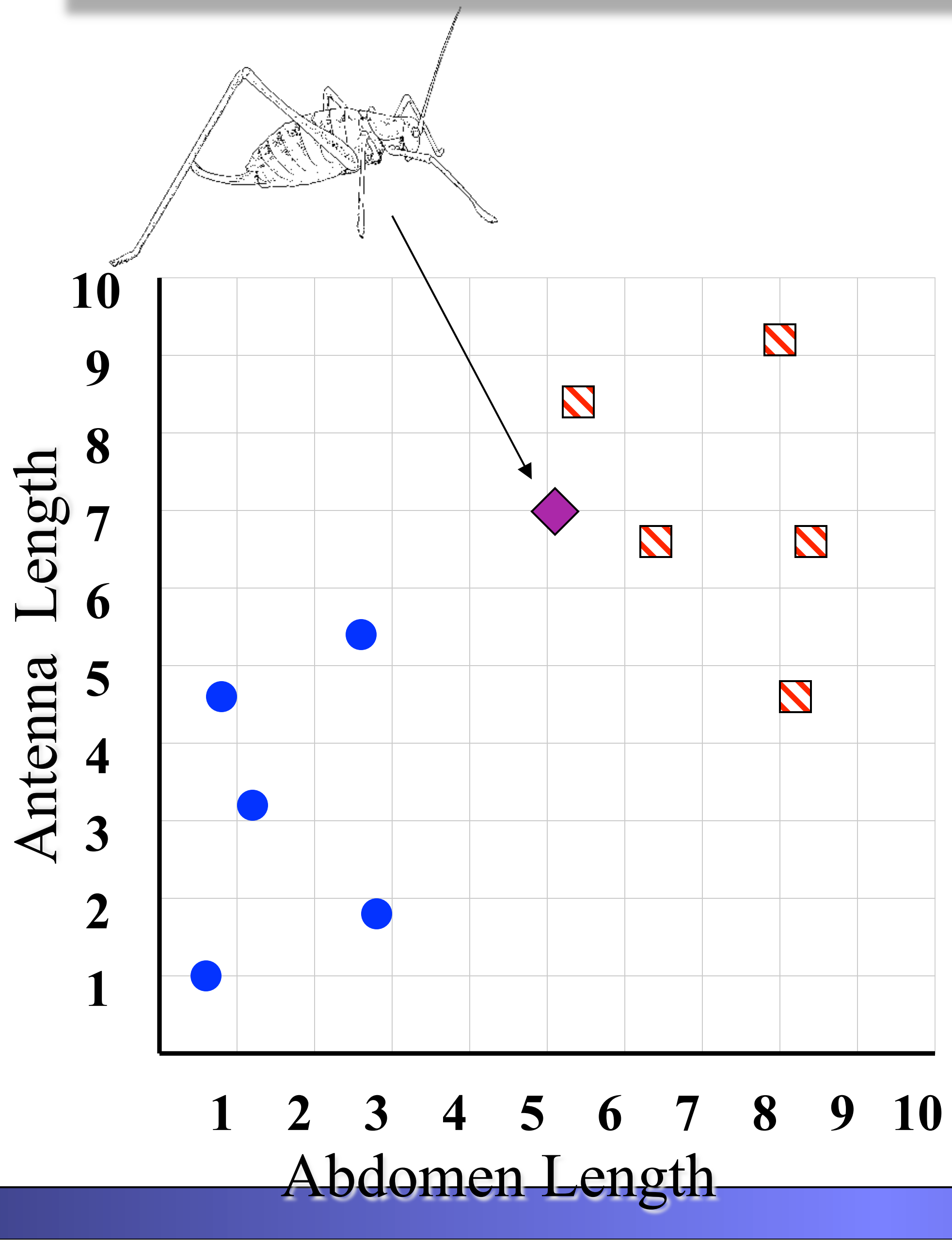
Grasshoppers

Katydids



previously unseen instance =

11	5.1	7.0	??????



We can “project” the previously unseen instance into the same space as the database.

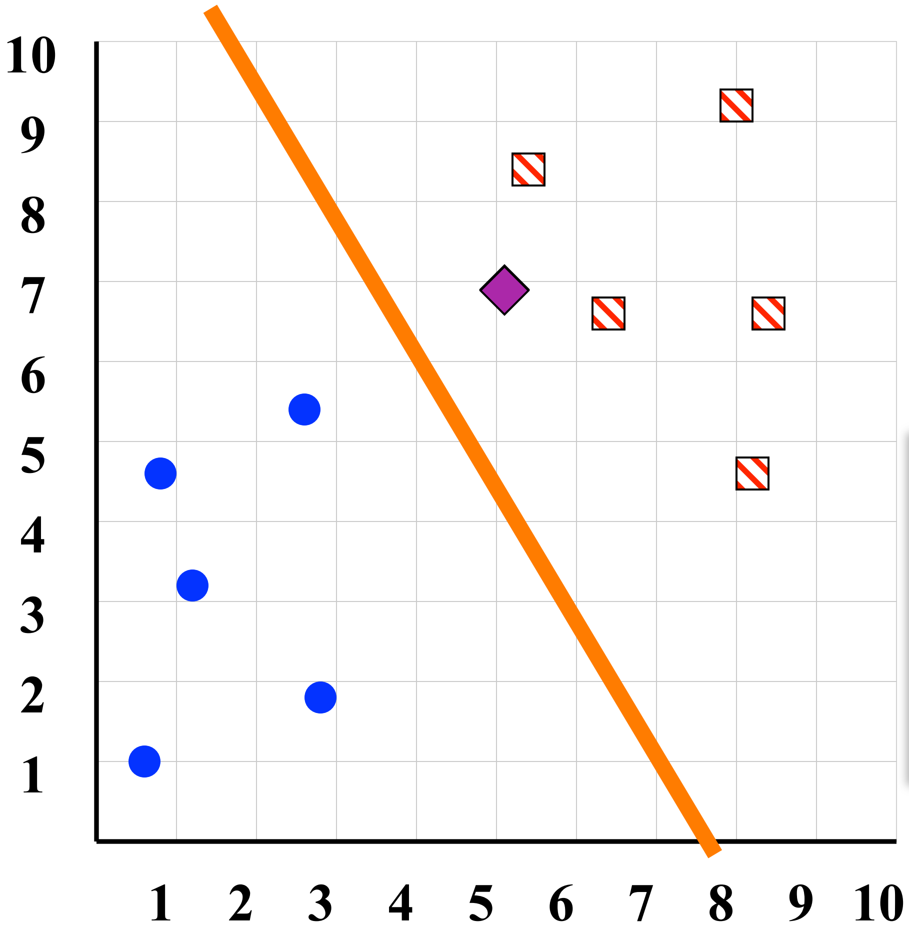
We have now abstracted away the details of our particular problem. It will be much easier to talk about points in space.

▨ Katydids

● Grasshoppers

Simple Linear Classifier

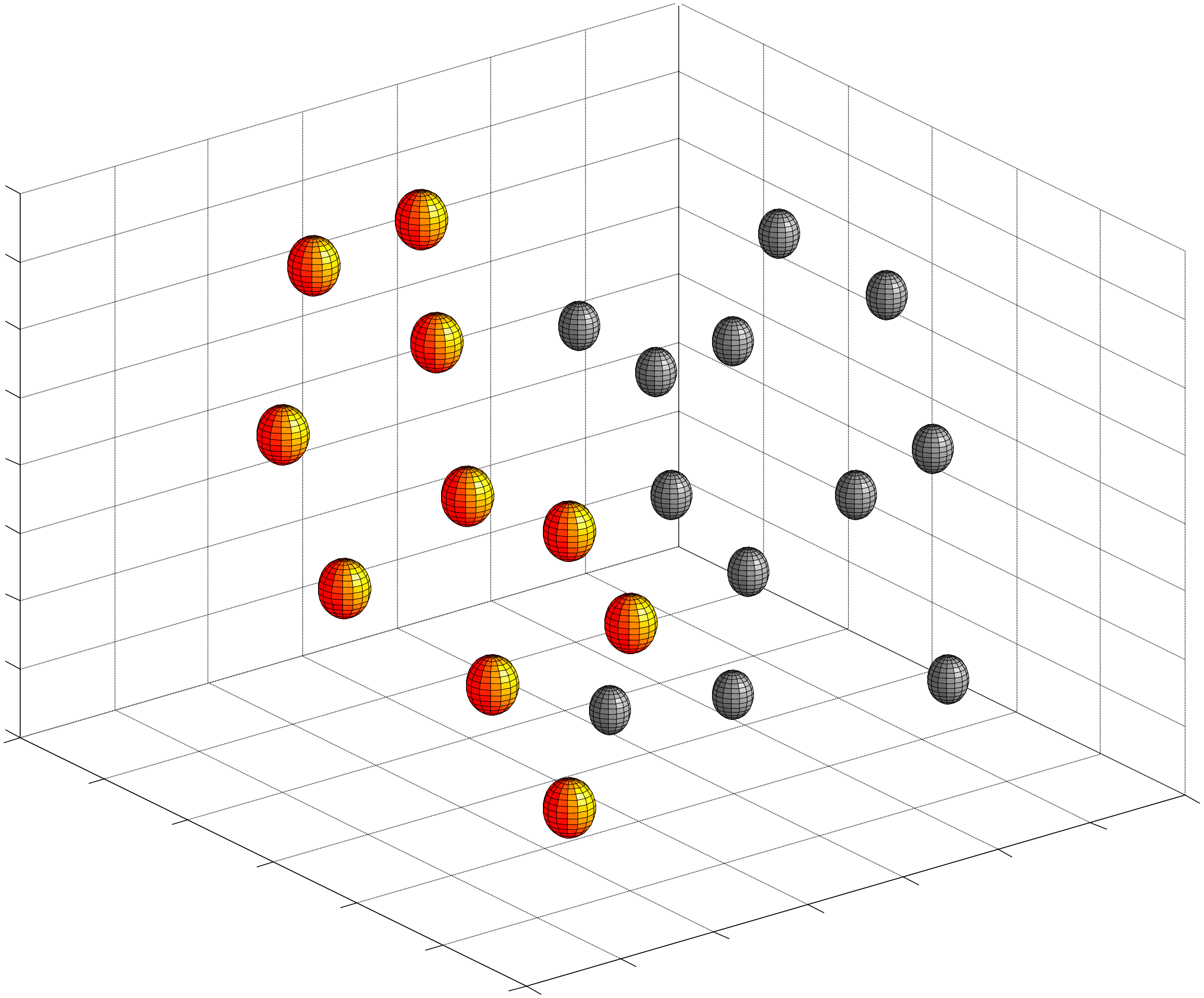
R.A. Fisher
1890-1962



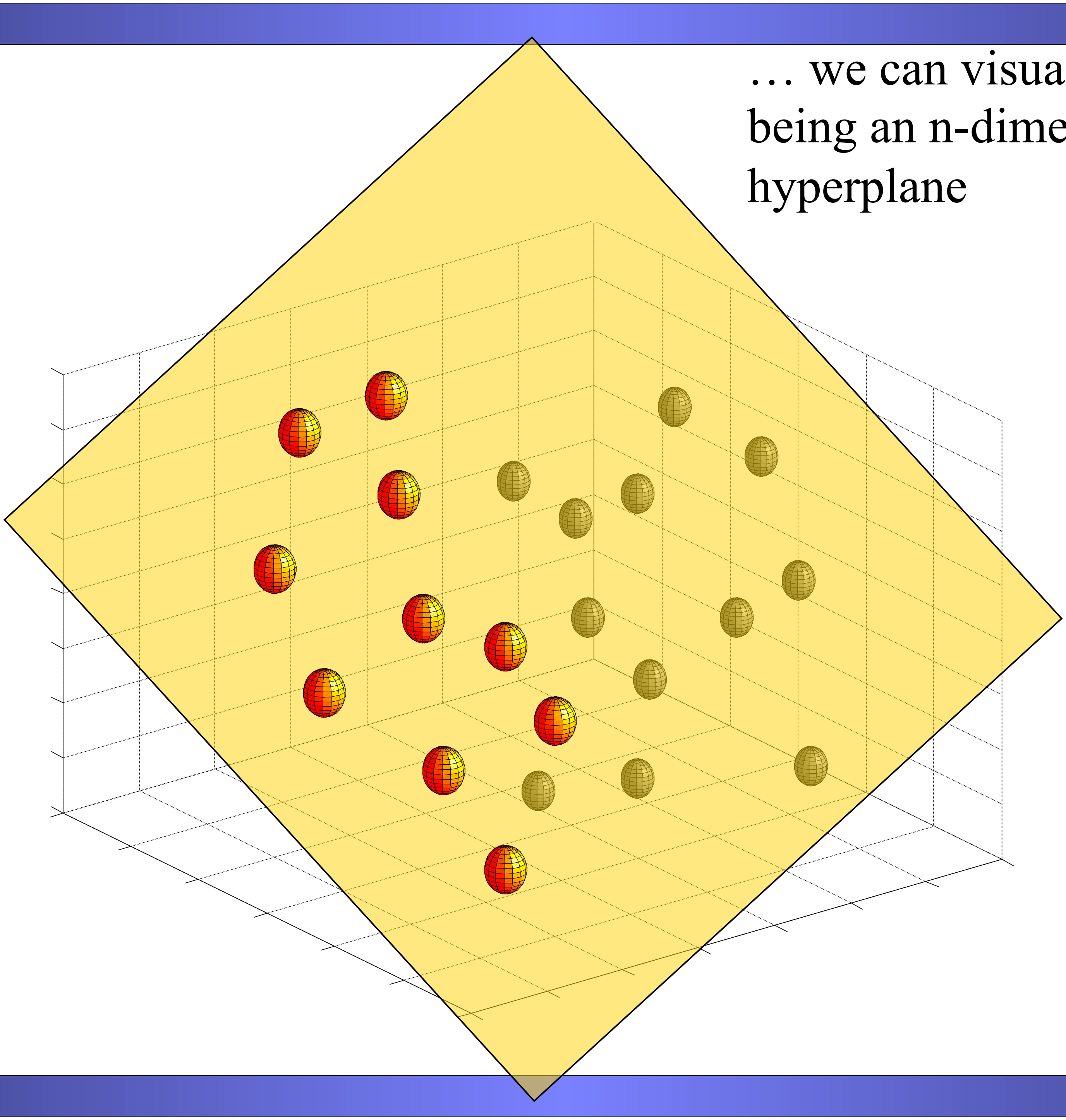
```
If previously unseen instance above the line
then
    class is Katydid
else
    class is Grasshopper
```

▨ **Katydids**
● **Grasshoppers**

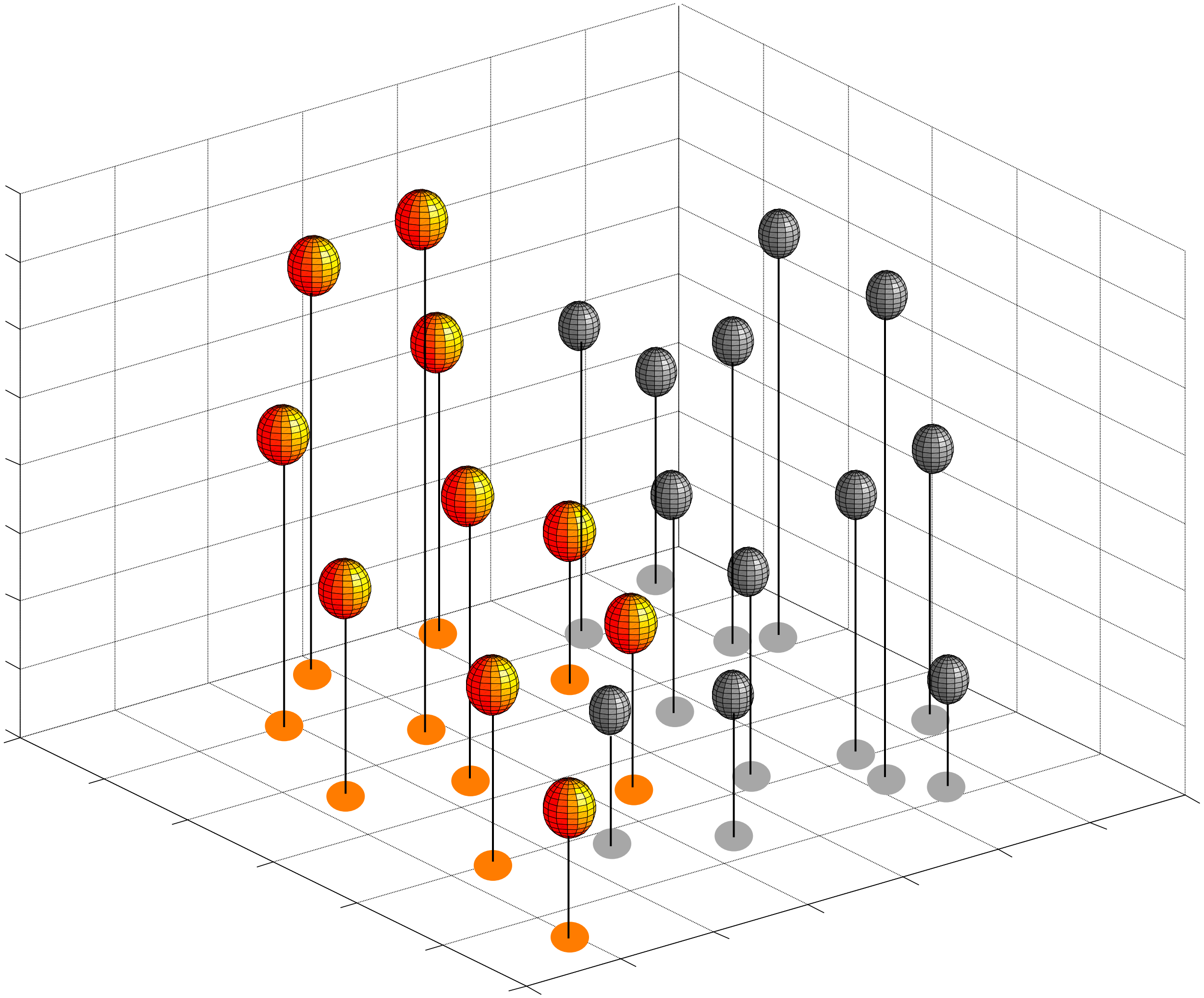
The simple linear classifier is defined for higher dimensional spaces…

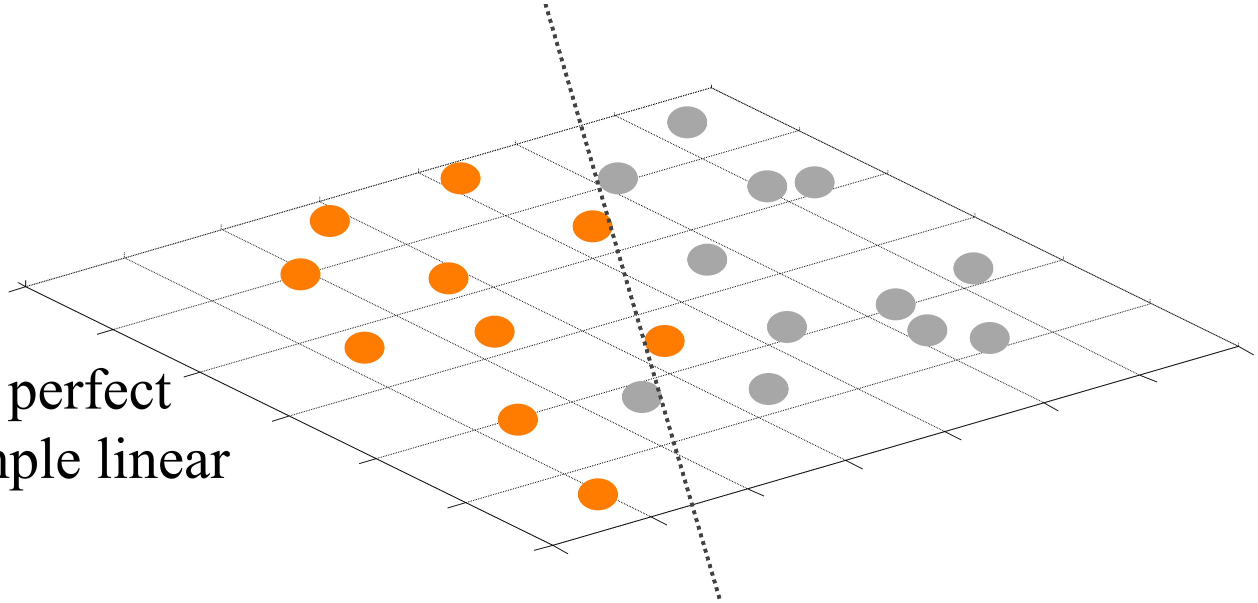


… we can visualize it as being an n-dimensional hyperplane



It is interesting to think about what would happen in this example if we did not have the 3rd dimension…

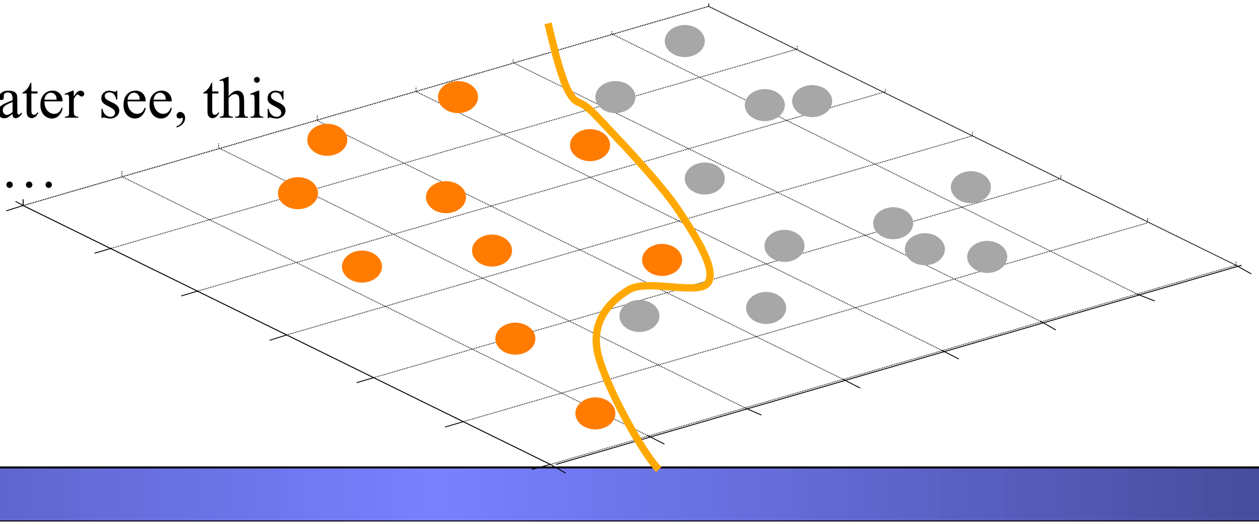




We can no longer get perfect accuracy with the simple linear classifier…

We could try to solve this problem by user a simple *quadratic* classifier or a simple *cubic* classifier..

However, as we will later see, this is probably a bad idea…

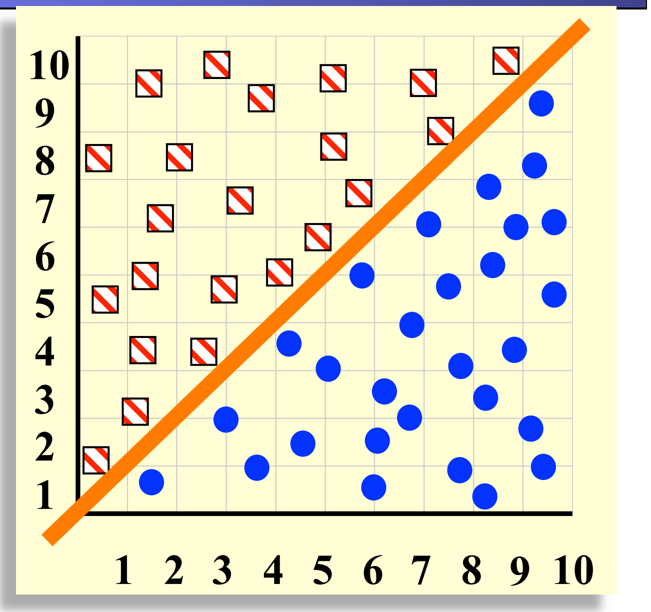


Which of the "Pigeon Problems" can be solved by the Simple Linear Classifier?

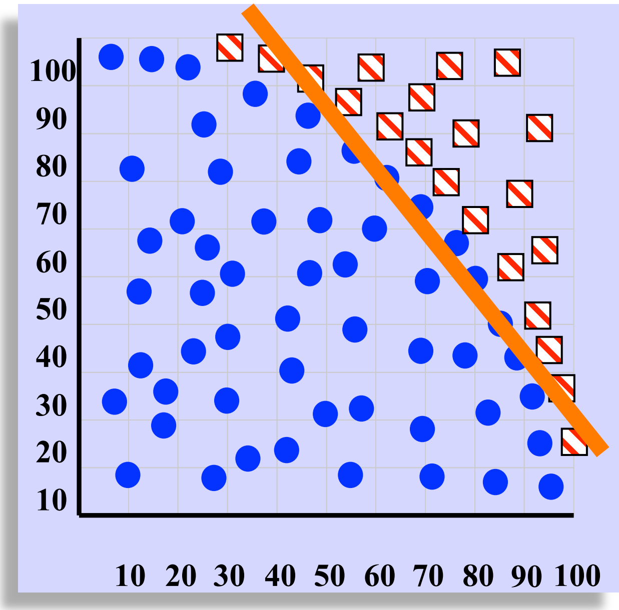
Perfect

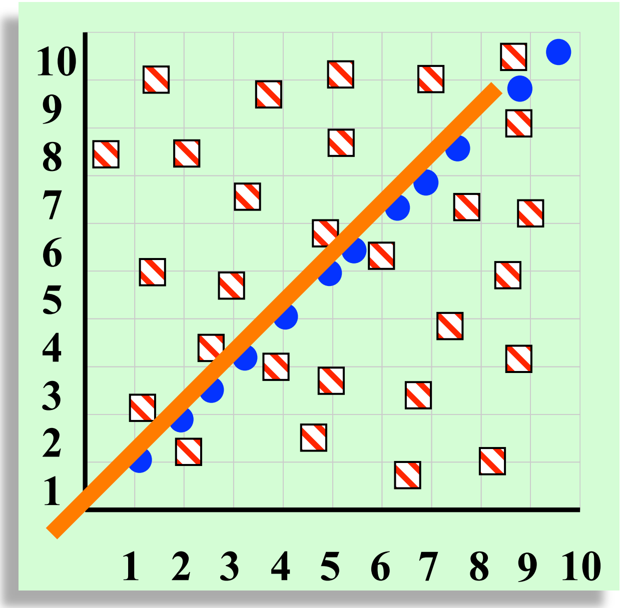
Useless

Pretty Good



Problems that can be solved by a linear classifier are called linearly separable.





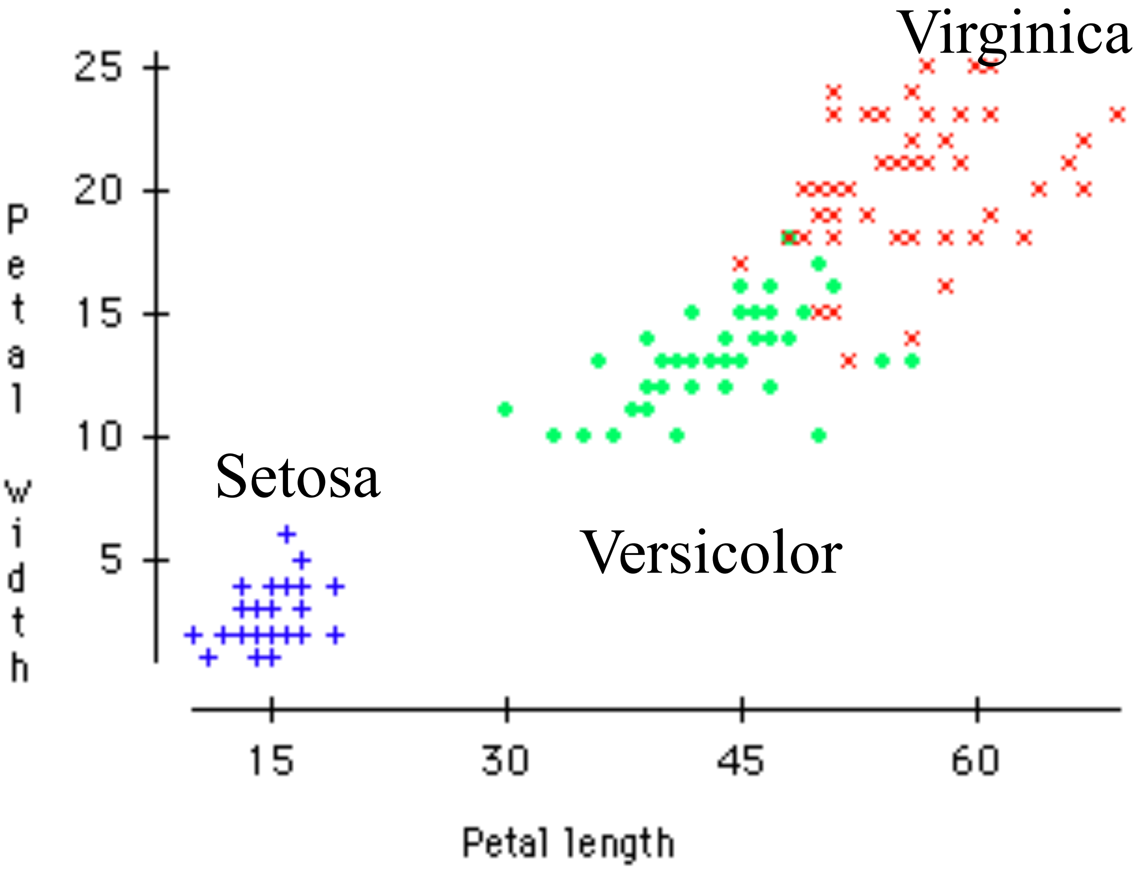
A Famous Problem

R. A. Fisher’ s Iris Dataset.

3 classes

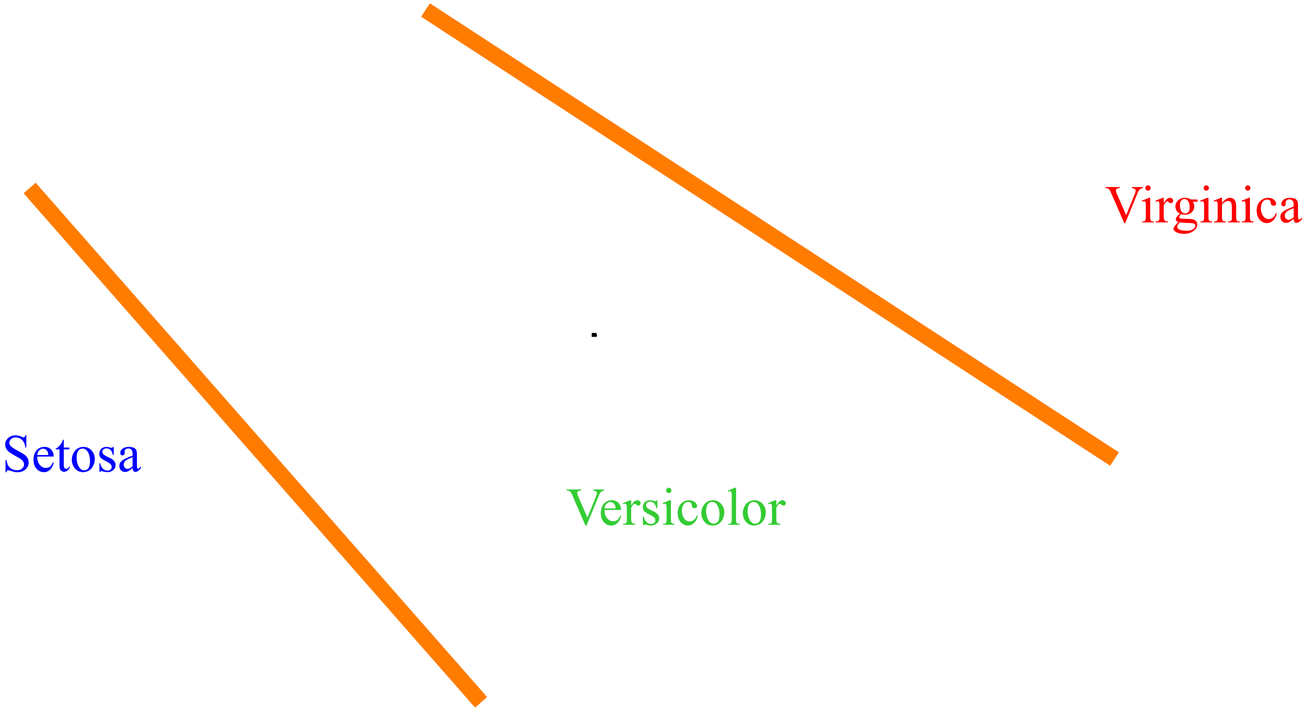
50 of each class

The task is to classify Iris plants into one of 3 varieties using the Petal Length and Petal Width.



Iris Setosa **Iris Versicolor** **Iris Virginica**

We can generalize the piecewise linear classifier to N classes, by fitting N-1 lines. In this case we first learned the line to (perfectly) discriminate between Setosa and Virginica/Versicolor, then we learned to approximately discriminate between Virginica and Versicolor.



If petal width > 3.272 – (0.325 * petal length) then class = Virginica
Elseif petal width…