Introduction to Bayesian Latent Class Models for diagnostic test evaluation

8 – 10 June 2022
Uppsala, Sweden

Practicalities

- SVA – room *Lånskeppet*
- Coffee breaks at 10:00 and at 14:30
- Lunch 12:00 – 13:00

- **Matt Denwood** (University of Copenhagen)
- **Arianna Comin** (Swedish National Veterinary Institute)
- **Maj Beldring Henningsen** (University of Copenhagen)
- **Eleftherios Meletis** (University of Thessaly)

Practicalities

All of the material is on the GitHub repository

→ We may tweak material as we go along

→ Remember to pull changes at the start of each day!

→ And click refresh in your browser . . !

Attendance registration is necessary for COST meetings

Harmony

COST action CA18208: https://harmony-net.eu/about/

October 2019 - October 2023

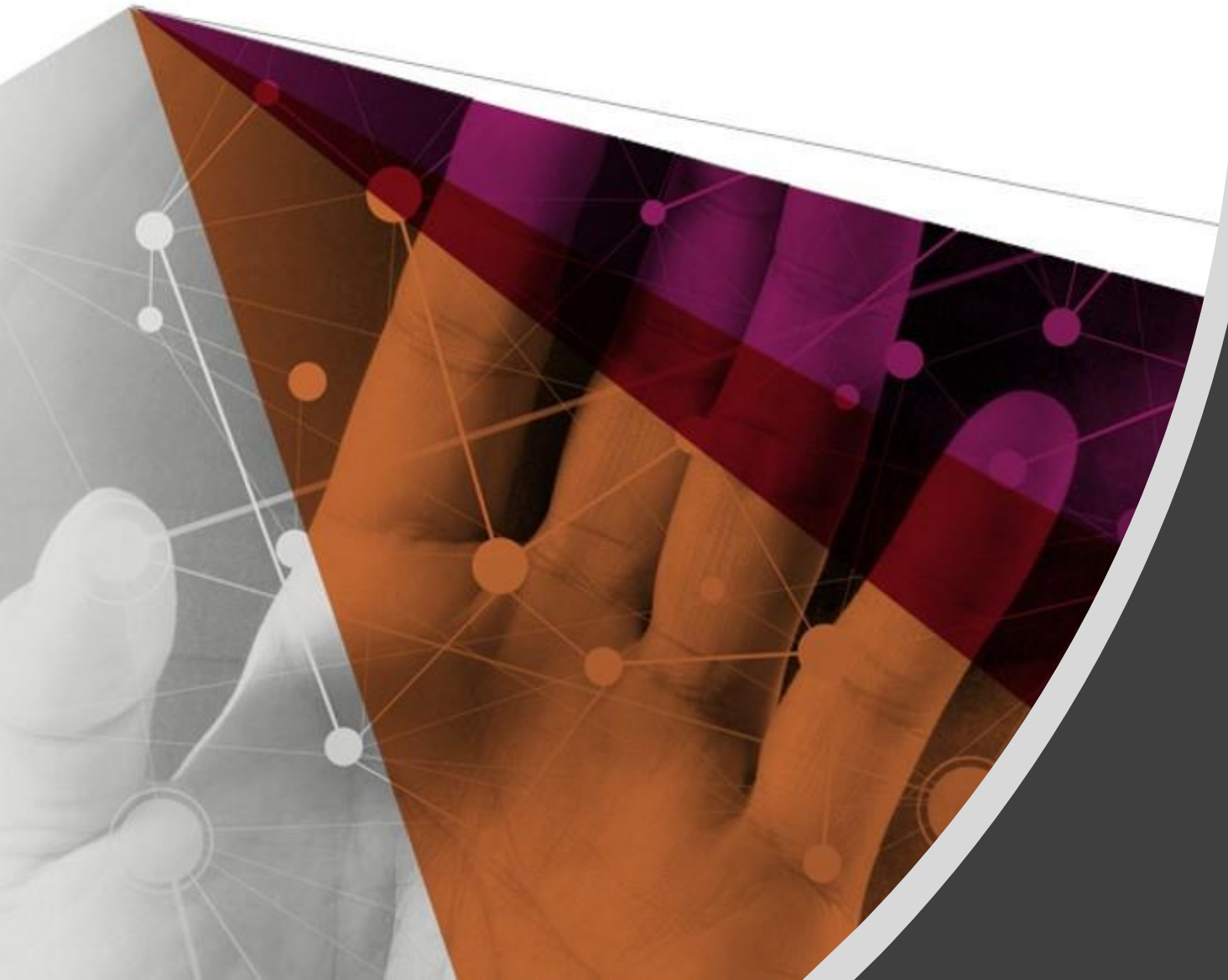
info@harmony-net.eu

Goals are to encourage the use of latent class models/methods for:

- → Diagnostic test evaluation
- → Determination of true prevalence
- → Certification of disease freedom

cost
EUROPEAN COOPERATION
IN SCIENCE & TECHNOLOGY

HARMONY



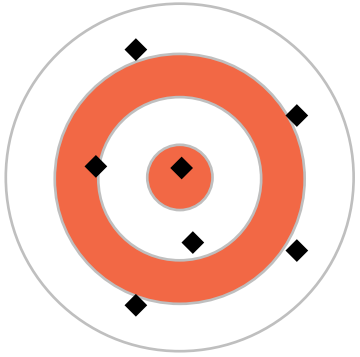
Background

Diagnostic test evaluation

Measuring test performance

Accuracy = ability to give the true measure of the substance being measured

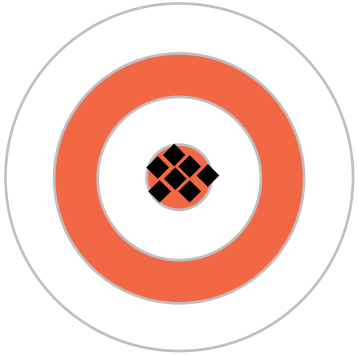
Precision = how consistent the results from the test are



Low accuracy
Low precision

Low accuracy
High precision

High accuracy
Low precision



High accuracy
High precision

Diagnostic test evaluation

Precision

- Coefficient of variation
- Pearson's correlation coefficient
- Concordance correlation coefficient
- Cohen's kappa

Accuracy

- Sensitivity
- Specificity

Sensitivity & Specificity

Analytic Sensitivity = lowest concentration of the chemical compound that the assay can detect

Analytic Specificity = ability of the test to react only to one chemical compound

Diagnostic Sensitivity = probability of a positive test result given that the subject is diseased

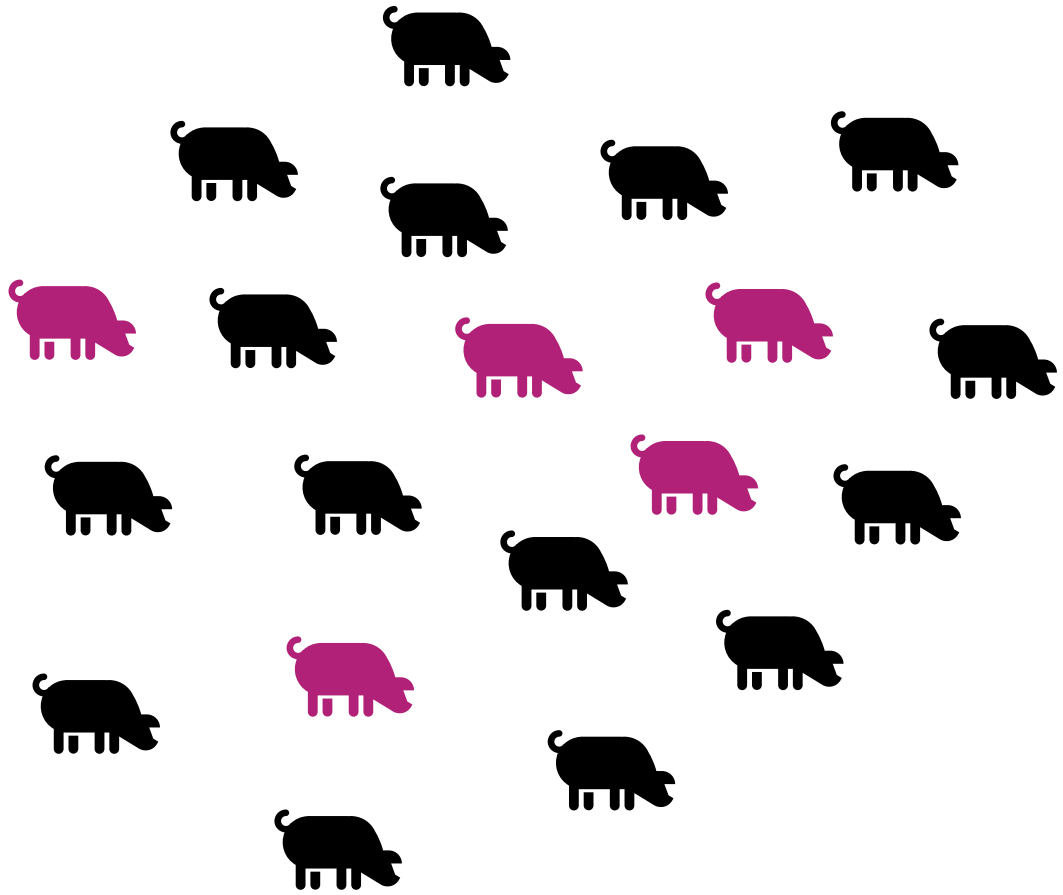
Diagnostic Specificity = probability of a negative test result given that the subject is not diseased

Why knowing diagnostic Se and Sp?

A quantification of the accuracy of a test allows to:

- calculate **predictive values** for a specific population (prevalence)
- calculate the accuracy of a **testing strategy** (serial/parallel testing)
- calculate the **true prevalence** of a sample/population
- estimate the **probability of freedom** from disease in a population

Estimating Se & Sp



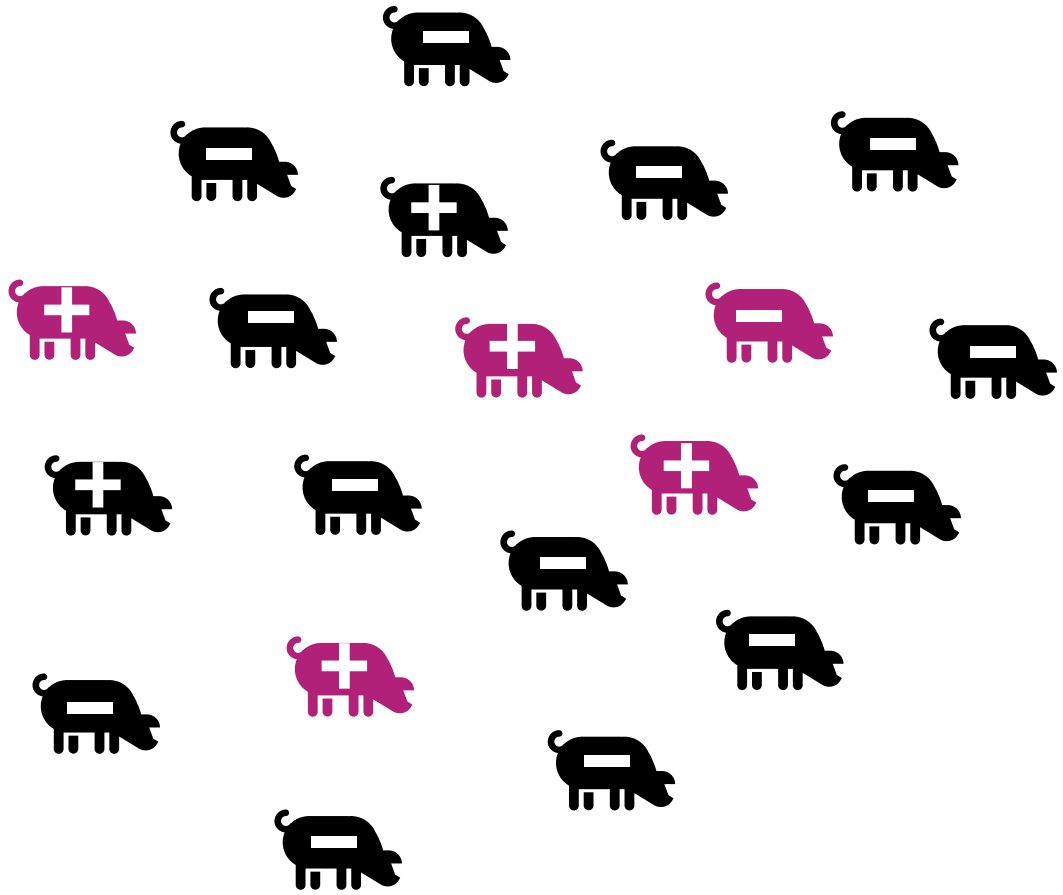
20 animals

↓

Disease

+	–
5	15

Estimating Se & Sp



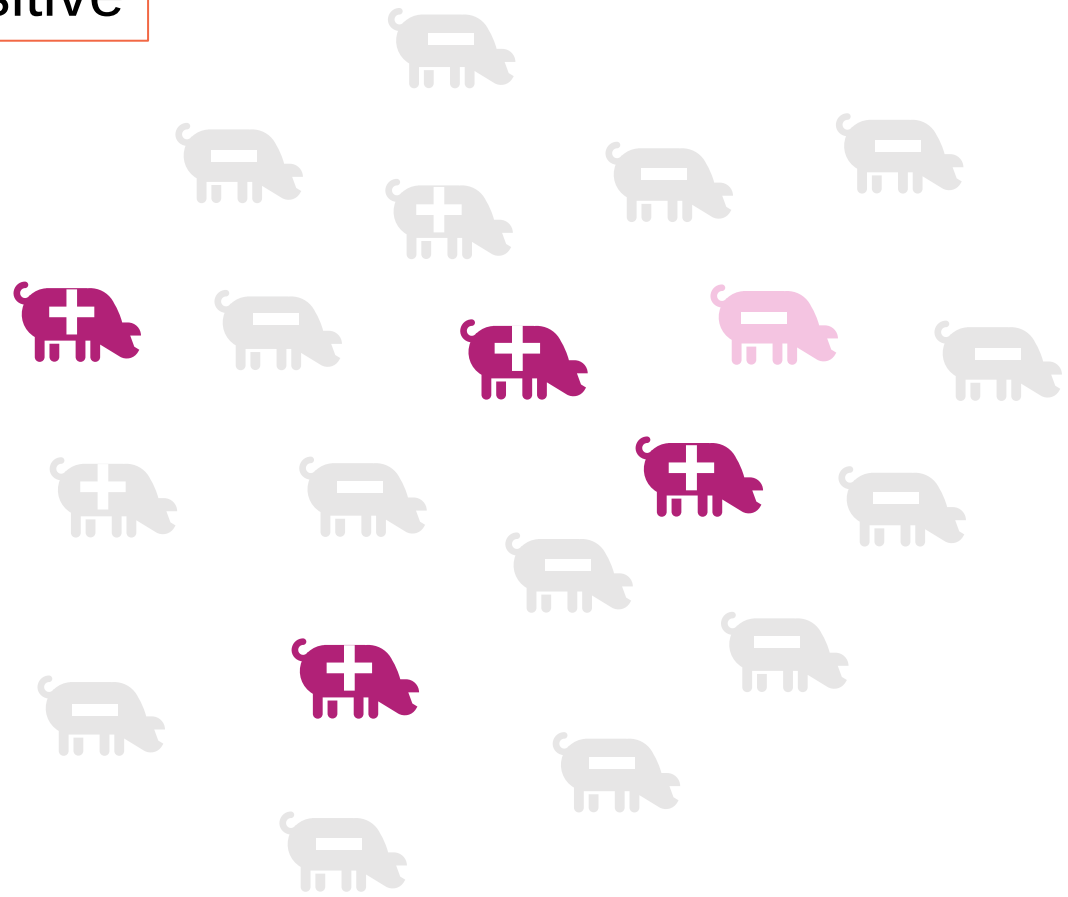
20 animals

Disease

Test	+	−
+		
−		
	5	15

Estimating Se & Sp

True Positive



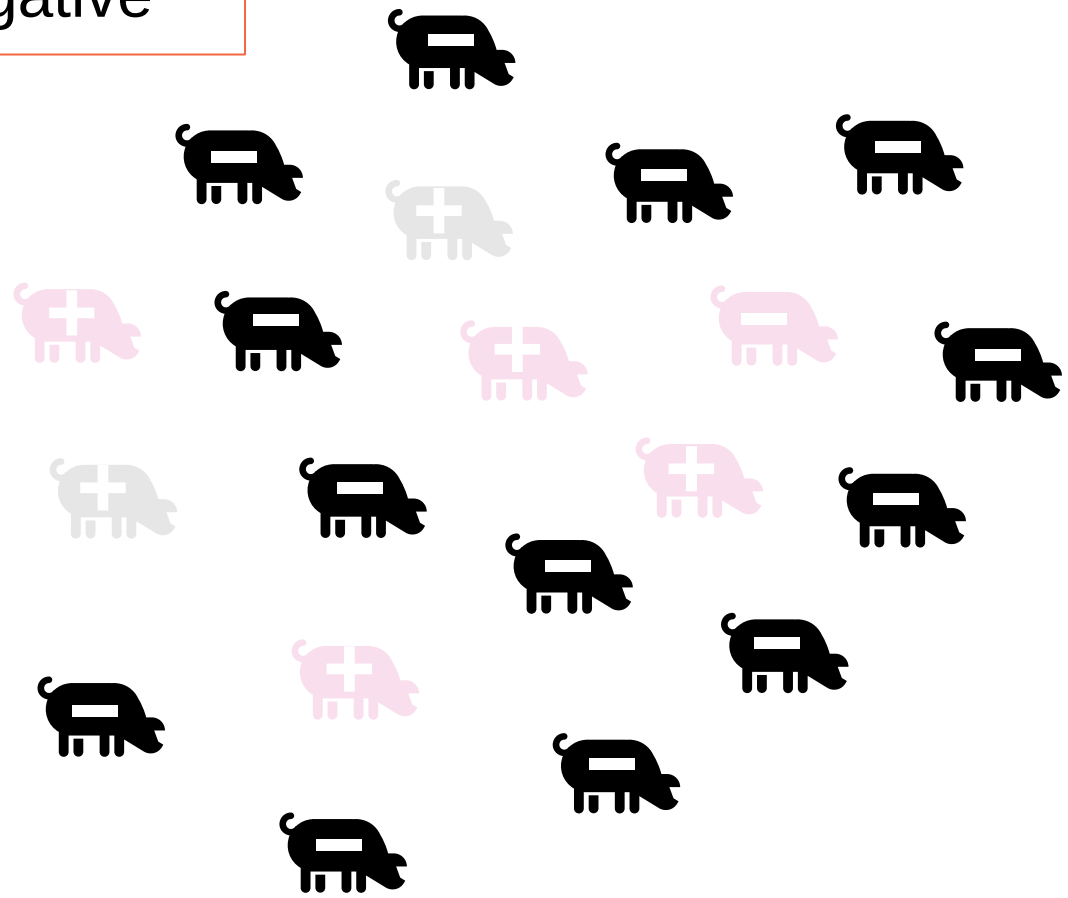
20 animals

Disease

Test	+	−
+	4 TP	
−		
	5	15

Estimating Se & Sp

True Negative



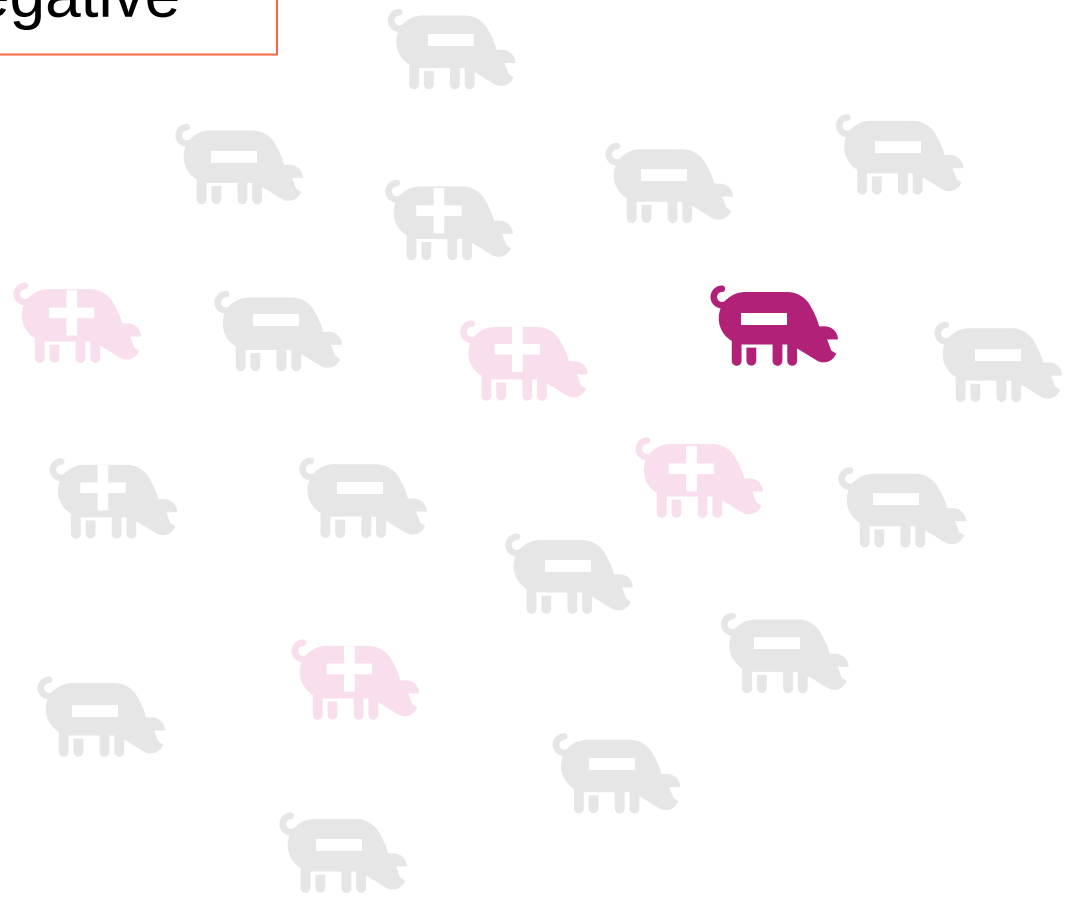
20 animals

Disease

Test		+	–
	+	4 TP	
	–		13 TN
		5	15

Estimating Se & Sp

False Negative



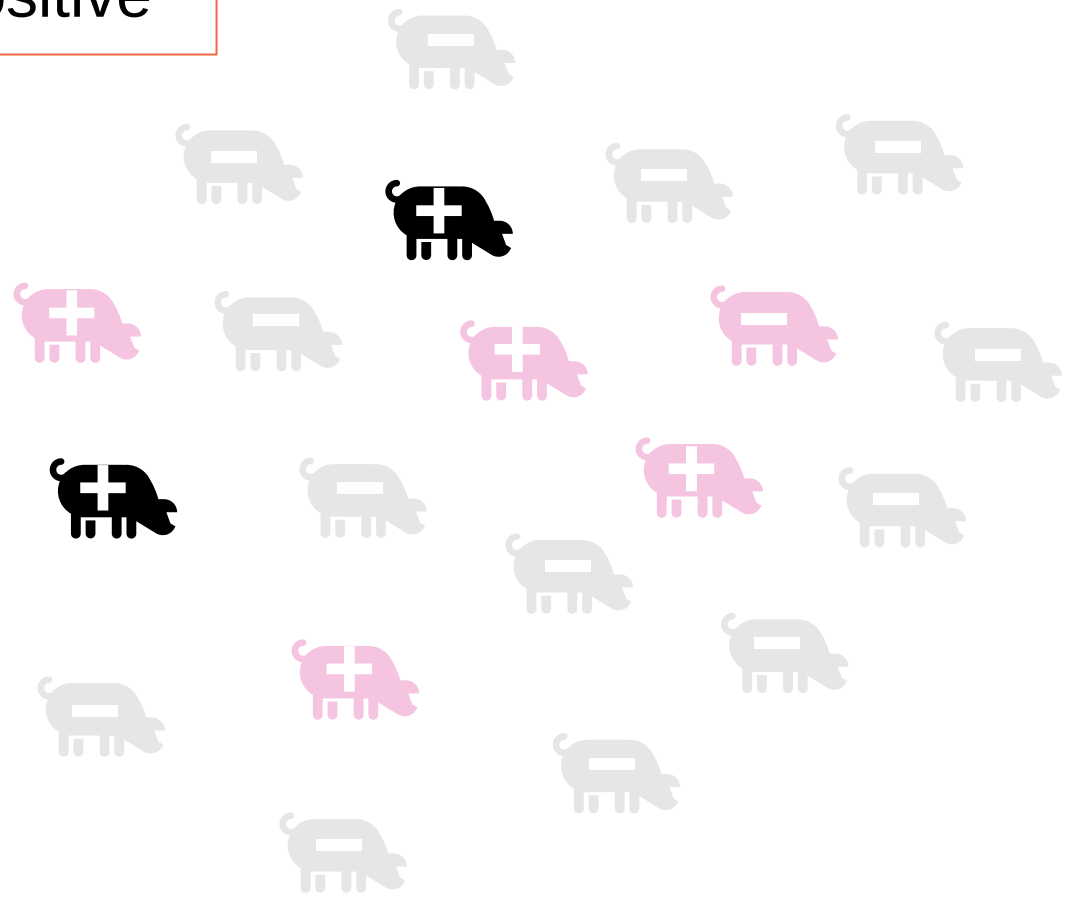
20 animals

Disease

Test		+	–
	+	4 TP	
	–	1 FN	13 TN
		5	15

Estimating Se & Sp

False Positive

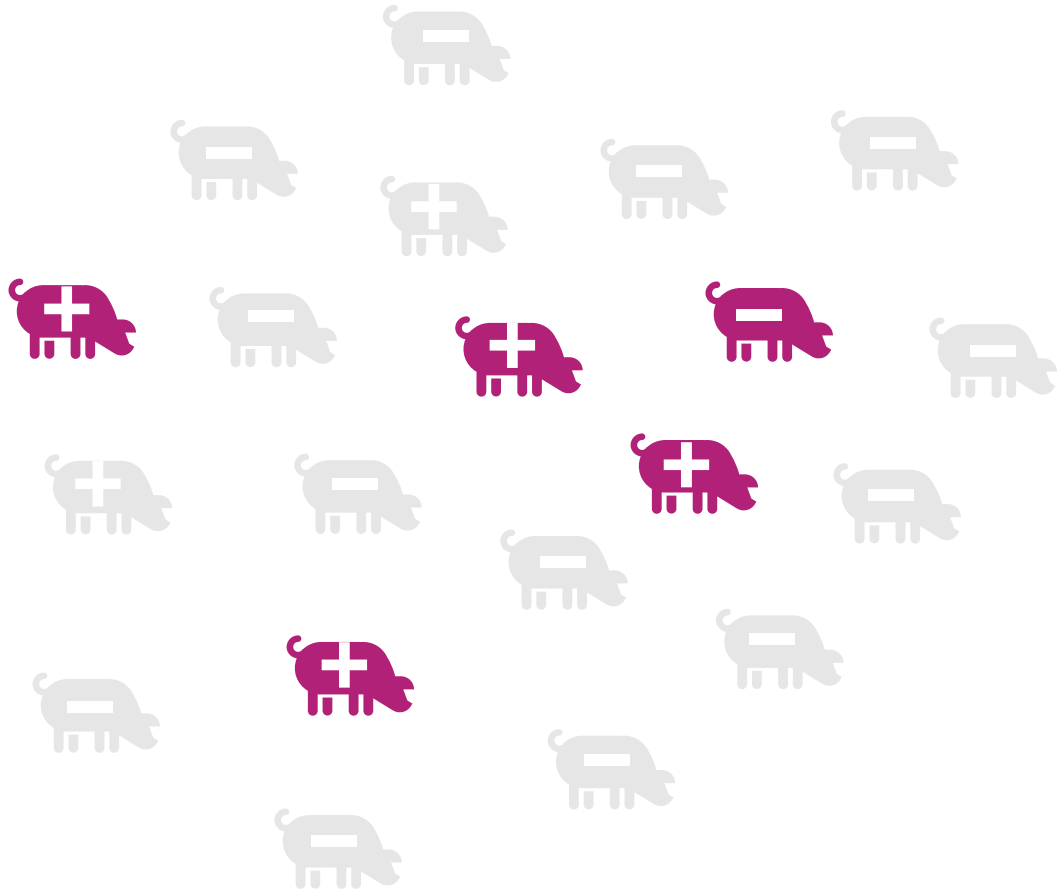


20 animals

Disease

Test		+	–
	+	4 TP	2 FP
	–	1 FN	13 TN
		5	15

Estimating Se & Sp



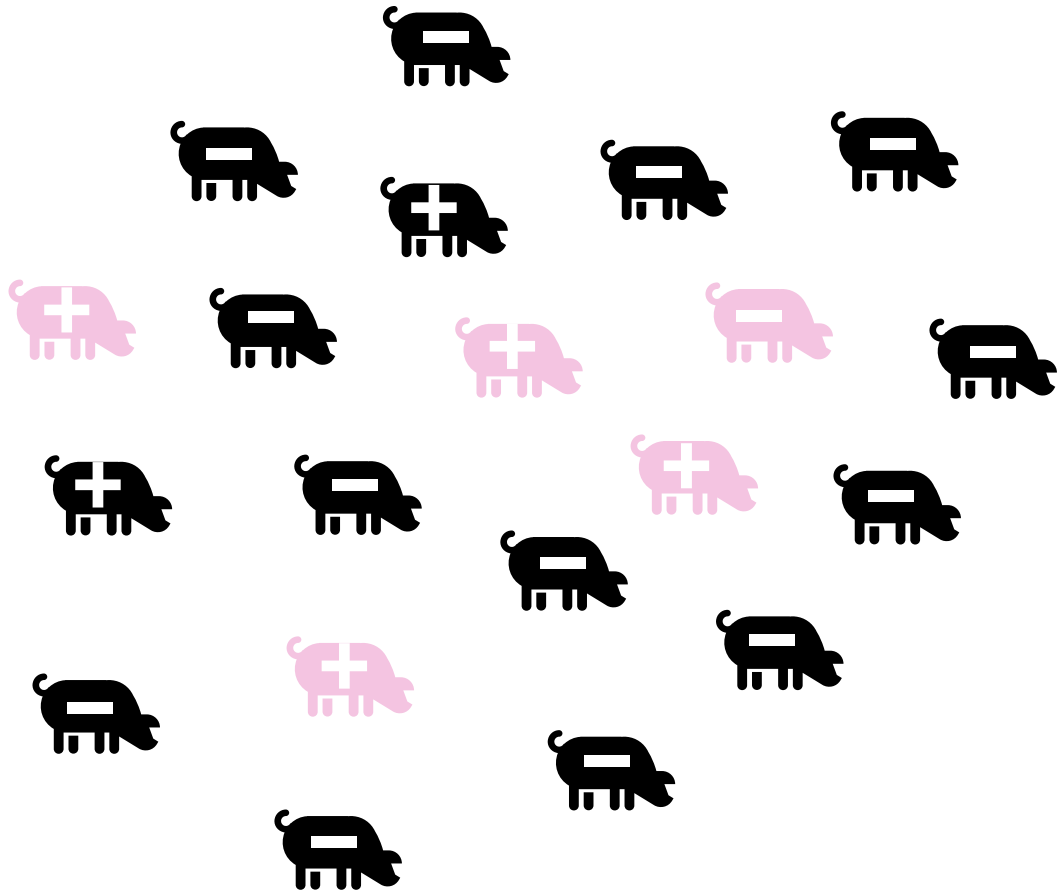
Sensitivity

p(T+|D+)

Test	Disease +	Disease −
+	4 TP	2 FP
−	1 FN	13 TN
	5	15

Se = TP / (TP+FN) = 4 / 5 = 0.80

Estimating Se & Sp



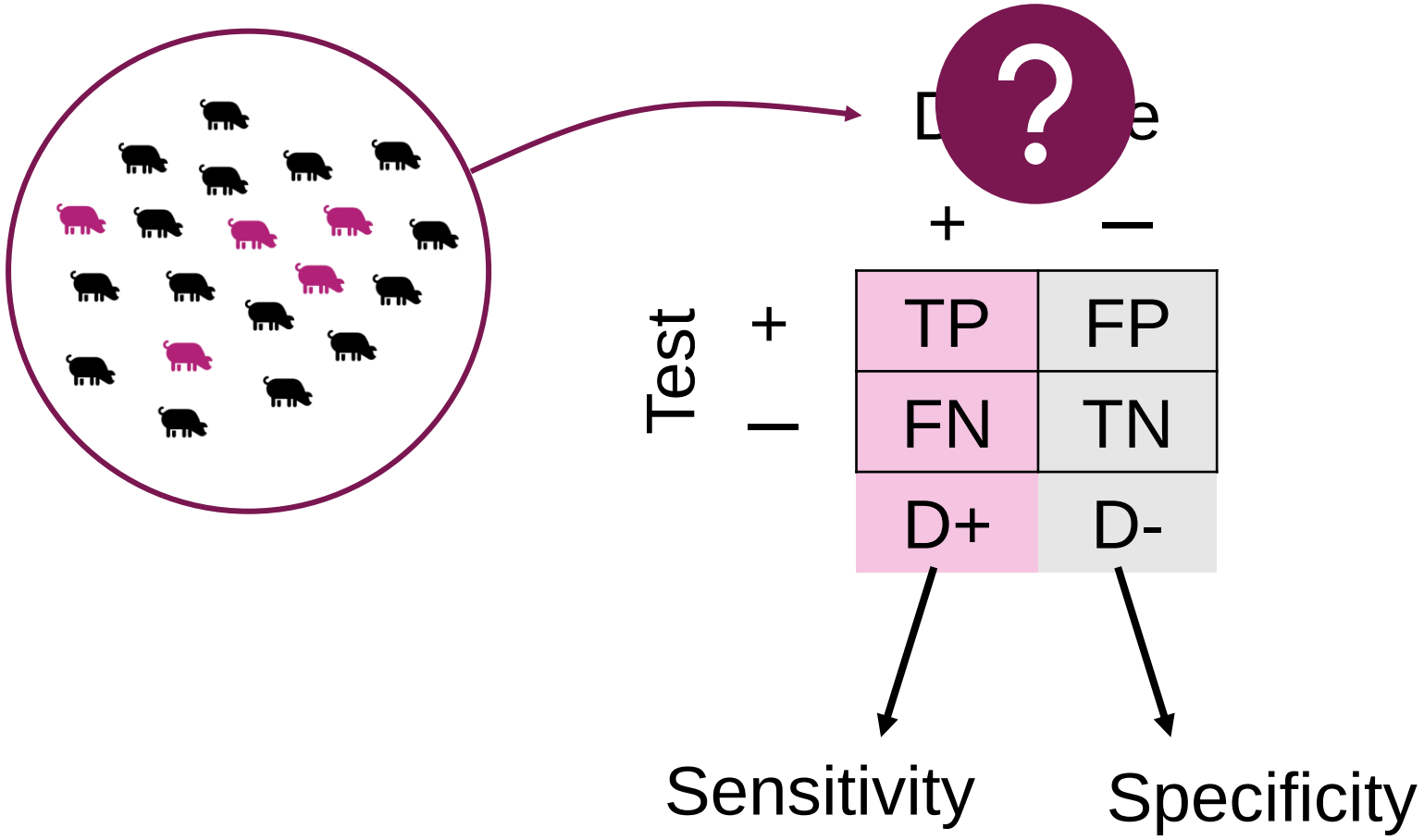
Specificity

p(T-|D-)

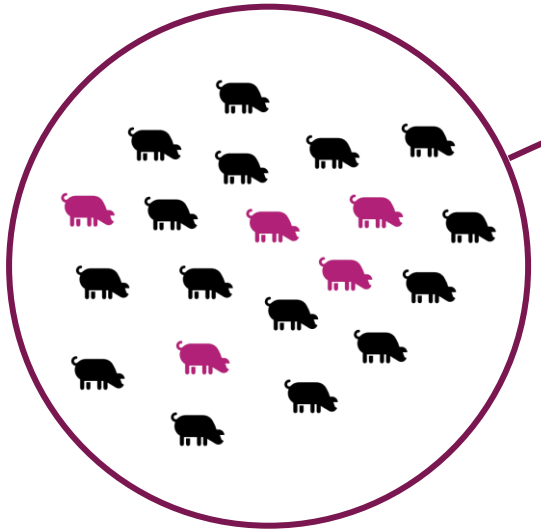
		Disease +	Disease −
Test	+	4 TP	2 FP
	−	1 FN	13 TN
		5	15

Sp = TN / (TN+FP) = 13 / 15 = 0.87

Estimating Se & Sp



Estimating Se & Sp



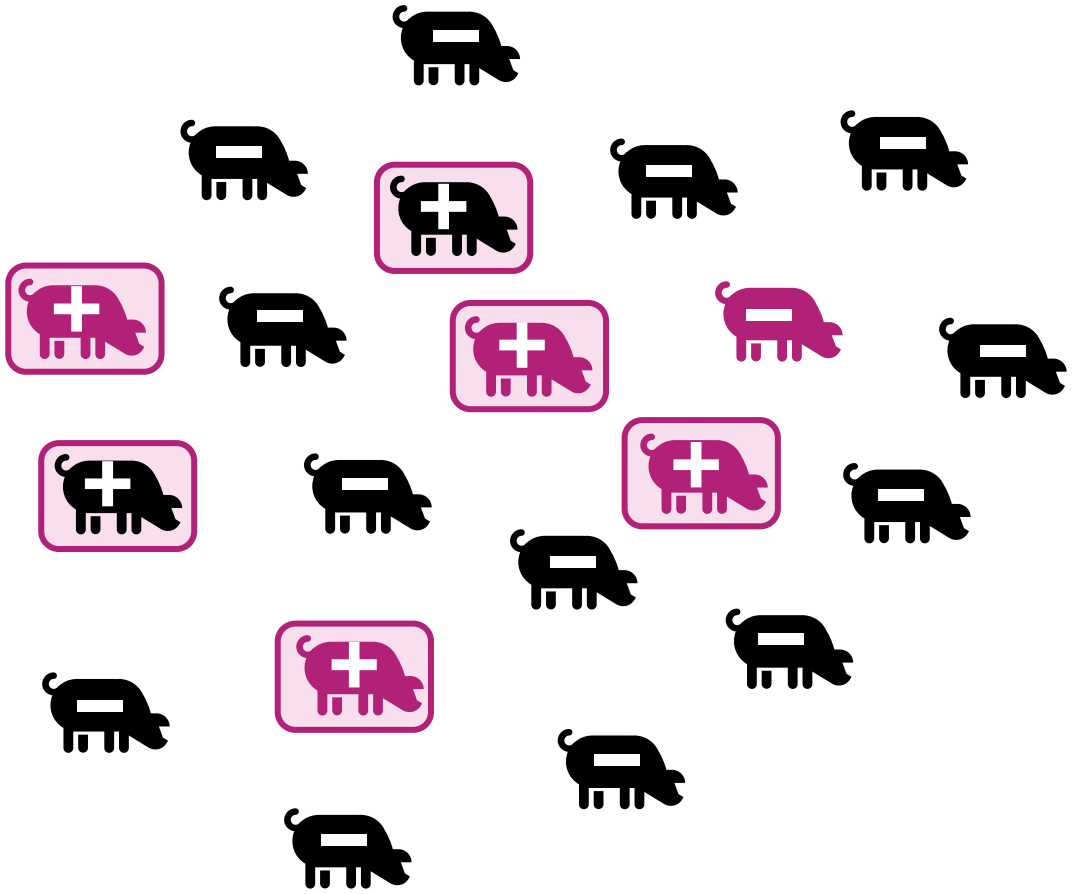
Gold standard

$Test_i$	$Test_R$ +	$Test_R$ −	
+	TP	FP	T_i+
−	FN	TN	T_i-
	T_R+	T_R-	

Sensitivity

Specificity

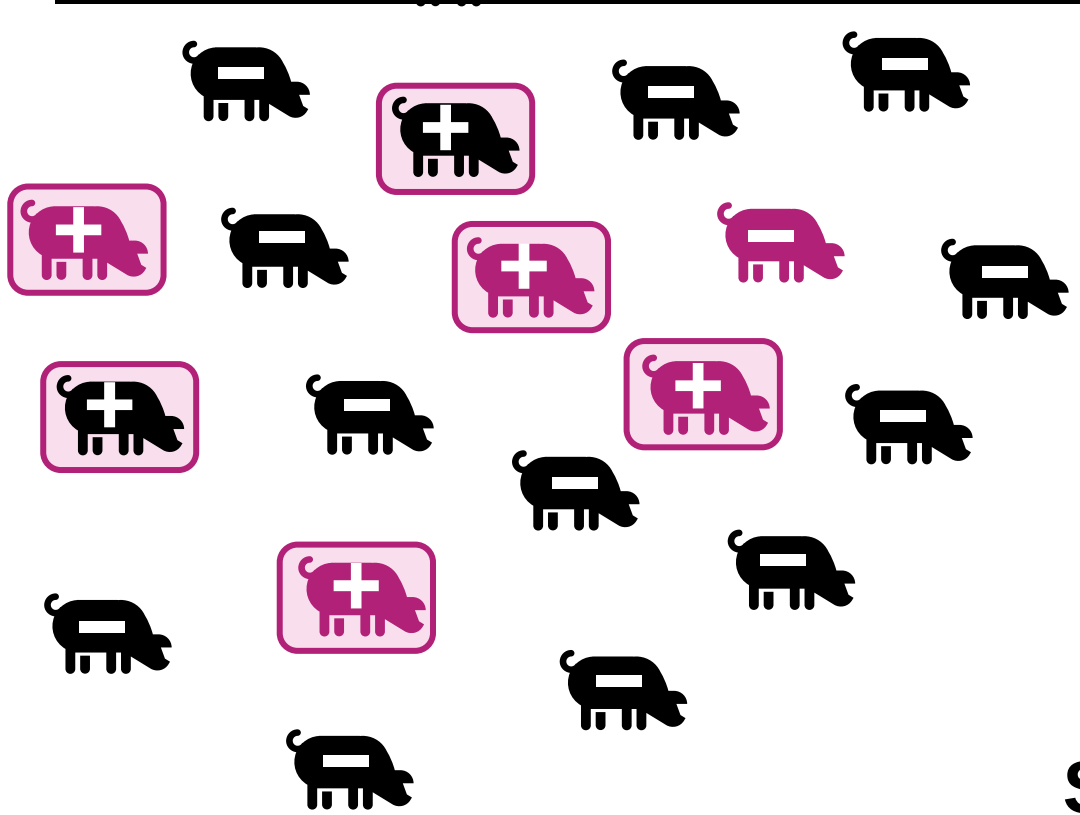
What if the reference test is not a GS?



$Test_R$	
+	–
6	14

What if the reference test is not a GS?

Biased estimates of the index test



		$Test_R$ +	$Test_R$ –	
$Test_I$	+	4	1	5
	–	2	13	15
		6	14	

Se = 4 / 6 = 0.67

Sp = 13 / 14 = 0.93

What if the reference test is not a GS?

Alternatives:

- Ignore the bias (not recommended!)
- Correct for the imperfect reference standard (⚠ need to know its Se/Sp)
- Use a composite reference standard (use multiple tests to infer the true disease status)
- Latent class models
  - Provide estimate of Se/Sp of the reference test as well
  - Allows for the index test to potentially perform better than the reference test