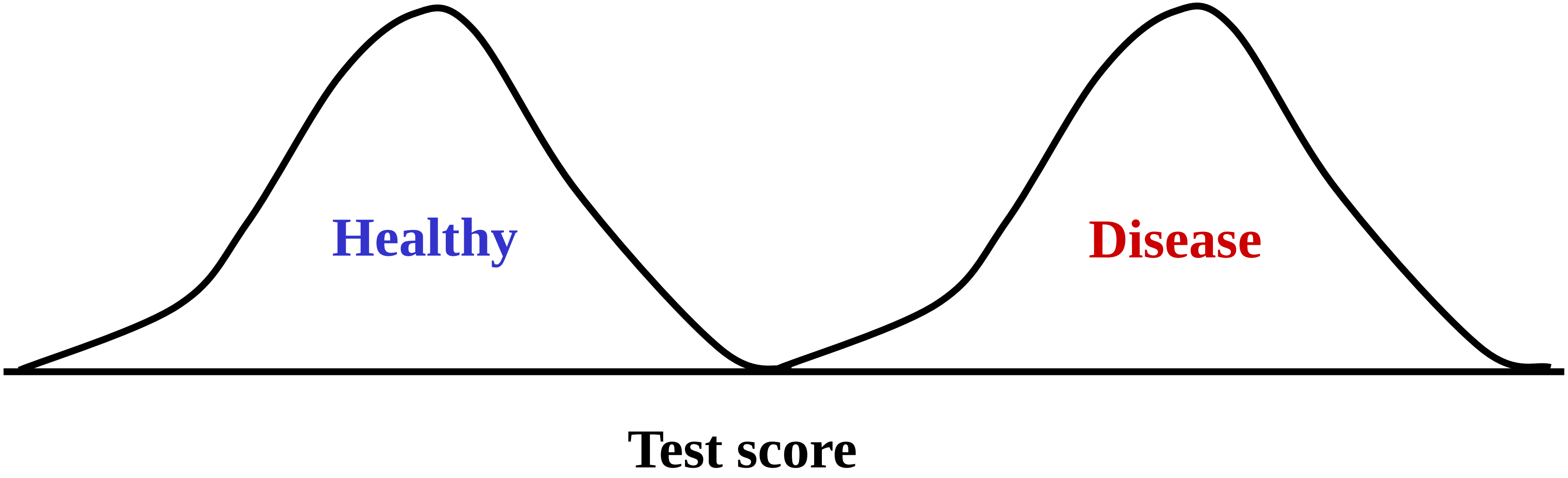
Sensitivity, specificity, and predictive value positive

Objectives

By the end of this session you should be able to:

- **Provide the definition of the terms sensitivity, specificity, predictive value positive and describe their importance to health practitioners and patients**
- **Describe the trade-offs between sensitivity and specificity**
- **Outline the factors that contribute to high predictive value positive**
- **Do calculation and interpretation of sensitivity, specificity, and predictive value positive from sample data.**
- **Diagnostic tests and likelihood ratios**

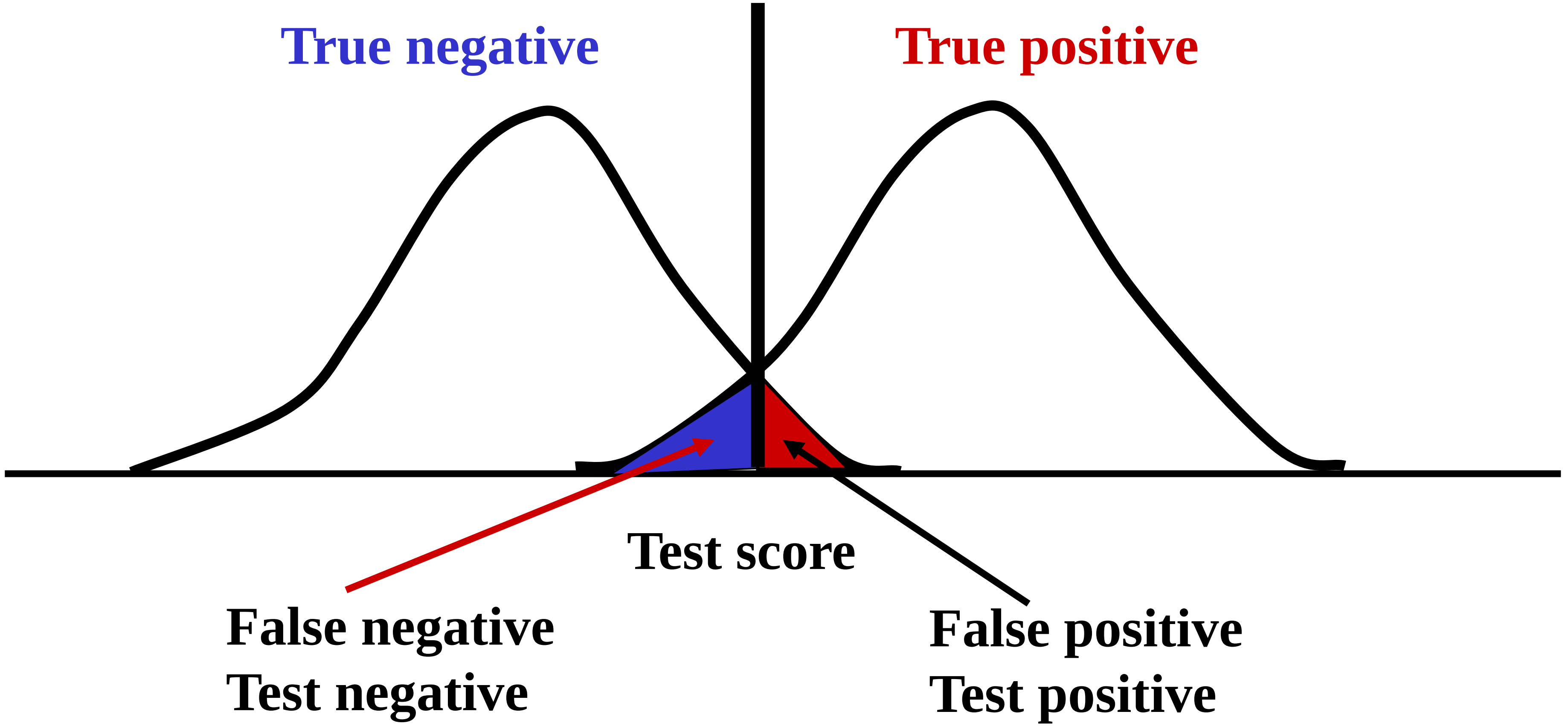
An ideal laboratory test would detect all people who have a disease and at the same time identify as normal all those who do not have the disease



Test based on continuous data

- **Hematocrit**
- **Blood glucose**
- **Optical density testing**

the values between normal/disease overlap



Validity of a test

How well a test performs can be assessed based on the values in the following 2x2 table

	Disease present	Disease absent
Test positive or Surveillance Detection positive	True Positives TP a	False positives FP b
Test negative or Surveillance Detection negative	c False negatives FN	d True negative TN

	Disease present	Disease absent
Test positive or Surveillance Detection positive	True Positives TP a	False positives FP b
Test negative or Surveillance Detection negative	c False negatives FN	d True negative TN

$$\text{Sensitivity} = \frac{\text{Diseased people with a positive test}}{\text{All diseased people}} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

$$\boldsymbol{Specificity} = \frac{\boldsymbol{Well\ people\ with\ a\ negaitive\ test}}{\boldsymbol{All\ well\ people}} = \frac{\boldsymbol{TN}}{\boldsymbol{TN} + \boldsymbol{FP}}$$

False positive rate

- The proportion of unaffected individuals with positive test results.

- False positive rate= $\frac{b}{b+d}$ =1-specificty

Predictive values

- Positive predictive value= all true positives/all positives(all true and all false) ×100
- How likely it is that a positive test result indicates the presence of the disease.
- It is the percentage of all people who test positive and who really have the disease
- Negative predictive value= True negatives/all negatives ×100
- It is the percentage of all people who test negative who really do not have the disease

	Disease present	Disease absent
Test positive or Surveillance Detection positive	True Positives TP **a**	False positives FP **b**
Test negative or Surveillance Detection negative	**c** False negatives FN	**d** True negative TN

$$prevalence = \frac{Diseased\ people}{All\ \ people} = \frac{TP + FN}{TP + FN + FP + TN}$$

$$predictive\ value\ \ positive = \frac{Diseased\ people\ with\ a\ positive\ test}{All\ \ people\ with\ a\ \ positive\ test} = \frac{TP}{TP + FP}$$

$$predictive\ value\ negative = \frac{Well\ people\ with\ a\ \ negative\ test}{All\ \ \ people\ with\ a\ \ negative\ test} = \frac{TN}{TN + FN}$$

		Patients with bowel cancer (as confirmed on colonoscopy)		
		Positive	*Negative*	
Fecal occult blood screen test outcome	*Positive*	True Positive (TP) = 20	False Positive (FP) = 180	→ Positive predictive value = TP / (TP + FP) = 20 / (20 + 180) = 20 / 200 = 10%
	Negative	False Negative (FN) = 10	True Negative (TN) = 1820	→ Negative predictive value = TN / (FN + TN) = 1820 / (10 + 1820) = 1820 / 1830 ≈ 99.5%
		↓ Sensitivity = TP / (TP + FN) = 20 / (20 + 10) = 20 / 30 ≈ 66.67%	↓ Specificity = TN / (FP + TN) = 1820 / (180 + 1820) = 1820 / 2000 = 91%	

For laboratory test the most critical values are:

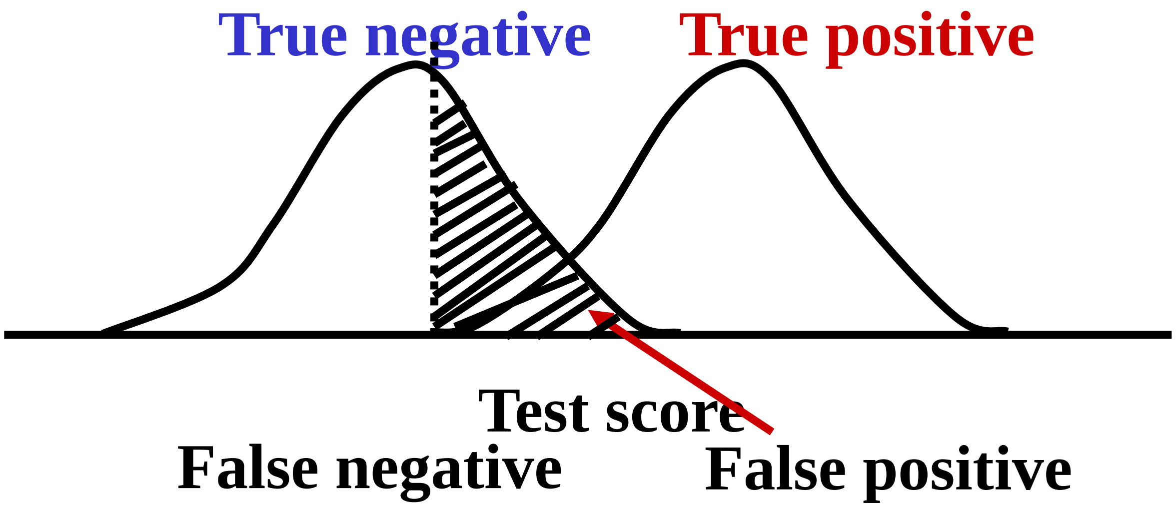
- **Sensitivity**
- **Specificity**
- **Predictive value positive**

For surveillance system the most critical values are:

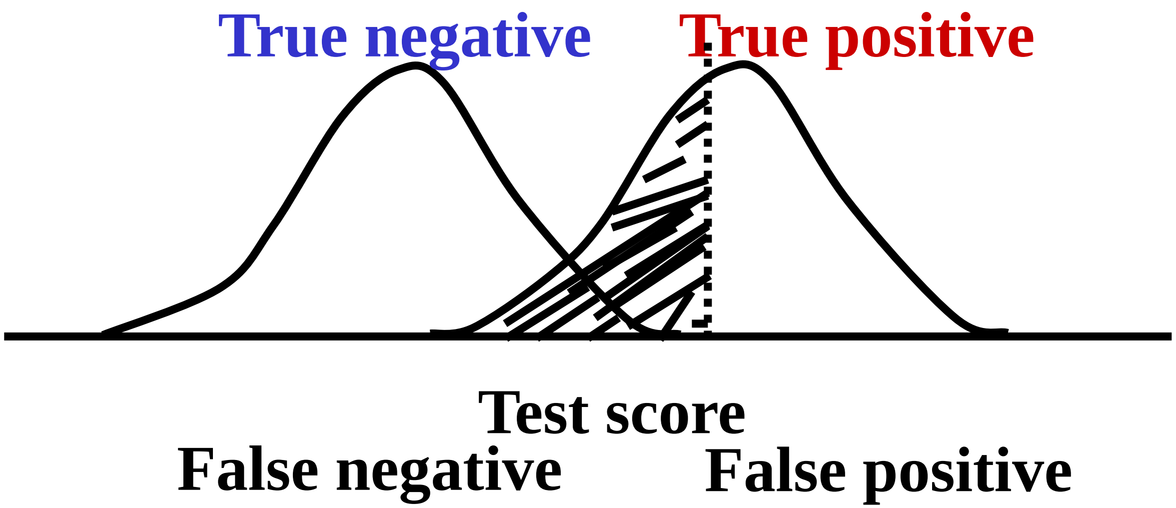
- **Sensitivity**
- **Predictive value positive**

Changing the cut-off point

Moving it down you increase FP.
Increased sensitivity, decreased specificity

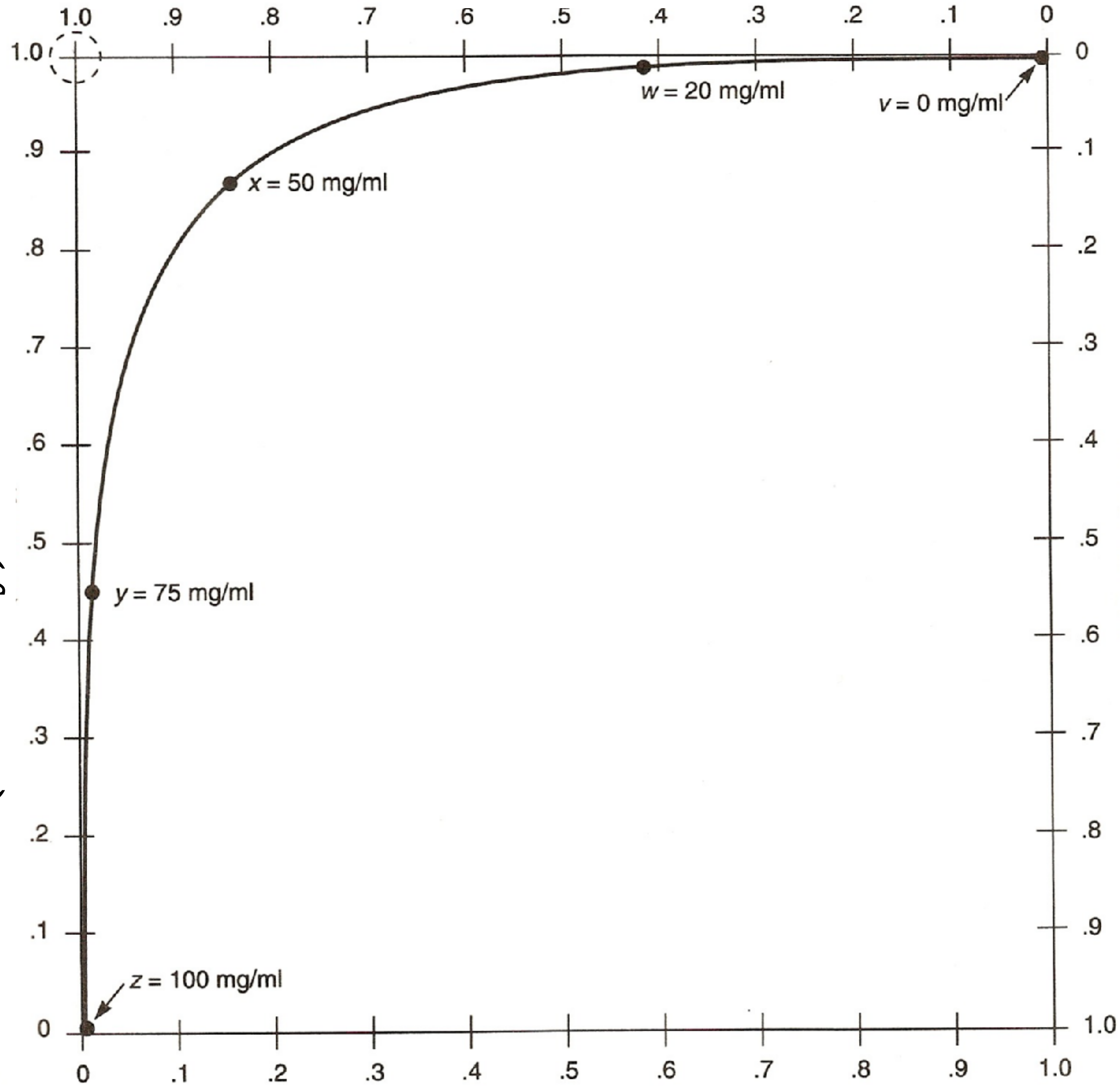


Moving it up you increase specificity and sensitivity will go down.



The receiver operating characteristic (ROC) curve

True negative rate
(specificity)



True positive rate
(sensitivity)

False negative rate
(1-sensitivity)

False positive rate
(1-specificity)

A hypothetical ROC curve. v, w, x, y, and z represent the five potential choices for the positivity criterion expressed in mg/ml

Sensitivity, specificity and the predictive value positive

- Sensitivity and specificity are independent of the prevalence of the disease

- Predictive value positive is dependent on the prevalence

Test applied to patients with eye problems

	Onchocerciasis (parasite)	
	present	absent
Test positive	215	16
Test negative	15	114

$$Sensitivity = \frac{215}{215+15} = 93\%$$

$$Specificity = \frac{114}{114+16} = 88\%$$

$$prevalence = \frac{215+15}{215+15+16+114} = 64\%$$

$$predictive\ value\ +ve = \frac{215}{215+16} = 93\%$$

$$predictive\ value\ -ve = \frac{114}{114+15} = 88\%$$

Notice the relationship between p+ve and the prevalence

Test applied to all patients seen in a clinic

	Onchocerciasis	
	present	absent
Test positive	215	248
Test negative	15	1822

$$Sensitivity = \frac{215}{215+15} = 93\%$$

$$Specificity = \frac{1822}{1822+248} = 88\%$$

$$prevalence = \frac{215+15}{215+15+248+1822} = 10\%$$

$$predictive\ value\ +ve = \frac{215}{215+248} = 46\%$$

$$predictive\ value\ -ve = \frac{1822}{1822+15} = 99\%$$

The higher the prevalence the higher the p+ve.

Application of sensitivity and specificity in surveillance

$$Sensitivity = \frac{Cases\ \ Detected\ by\ \ Surveillance}{all\ \ diseased\ \ people} = \frac{TP}{TP + FN}$$

$$Specificity = \frac{well\ \ people\ considered\ -ve\ by\ \ surveillance}{all\ \ well\ \ people} = \frac{TN}{TN + FP}$$

$$predictive\ value\ ve = \frac{Diseased\ \ Detected\ by\ \ Surveillance}{all\ \ people\ meeting\ \ the\ \ case\ \ definition} = \frac{TP}{TP + FP}$$

In surveillance, the two most important values are:

- **Sensitivity**
- **Predictive value positive**

Sensitivity is affected by:

- **Whether people with the condition seek medical care**
- **Whether the disease is diagnosed**
- **Whether the disease is reported**

Need a survey to evaluate sensitivity

- **Predictive value positive is important in outbreak investigation. If P+ve is low, resources will be wasted chasing problems do not exist**
- **Increasing the criteria to make a diagnosis will increase the specificity**
- **Using a broad case definition will improve sensitivity**

Odds of being affected given a positive result (OAPR):

- OAPR is the ratio of the number of affected individuals among those with positive test results, i.e. true postives:false positives
- Odds of being affected given a positive result (OAPR)= all true positives: all false positives

Diagnostic tests and likelihood ratios

The properties of a diagnostic or screening test are often described using:

- **sensitivity**
- **Specificity**
- **predictive**

Reference: Jonathan J Deeks and Douglas G Altman. Diagnostic tests 4: likelihood ratios. BMJ 2004;329;168-169

Likelihood ratios

LR: is the number of times individuals with positive results are more likely to have the disorder for which they are being tests compared with individuals who have not been tested.

Each test result has its own likelihood ratio, which summarises how many times more (or less) likely patients with the disease are to have that particular result than patients without the disease.

The likelihood ratio (LR) is the detection rate (sensitivity) divided by the false positive rate (DR/FPR)

LR> 1 indicates that the test result is associated with the presence of the disease
LR< 1 indicates that the test result is associated with the absence of disease.

The further likelihood ratios are from 1 the stronger the evidence for the presence or absence of disease.

LR> 10 provide strong evidence to rule in diagnosis

LR<0.1 provide strong evidence to rule out diagnosis

When tests report results as being either positive or negative the two likelihood ratios are called the positive likelihood ratio and the negative likelihood ratio.

Results of a study of the value of a history of smoking in diagnosing obstructive airway disease.

Likelihood ratios are ratios of probabilities, and can be treated in the same way as risk ratios for the purposes of calculating confidence intervals[6]

Smoking habit (pack years)	Obstructive airway disease		Likelihood ratio	95% CI
	Yes (n (%))	No (n (%))		
≥40	42 (28.4)	2 (1.4)	(42/148)/(2/144)=20.4	5.04 to 82.8
20-40	25 (16.9)	24 (16.7)	(25/148)/(24/144)=1.01	0.61 to 1.69
0-20	29 (19.6)	51 (35.4)	(29/148)/51/144)=0.55	0.37 to 0.82
Never smoked or smoked for <1 yr	52 (35.1)	67 (46.5)	(52/148)/67/144)=0.76	0.57 to 1.00
Total	148 (100)	144 (100)		

- **A smoking history > 40 pack years is strongly predictive of a diagnosis of obstructive airway disease as the LR >10**

- **Although never smoking or smoking less than 20 pack years both point to not having OAD, their LRs are not small enough to rule out the disease with confidence.**

For 2x2 table , likelihood ratios can be calculated directly from sensitivities and specificities.

Smoking habit (pack years)	Obstructive airway disease	
	Yes	No
≥40	42	2
<40	106	142
	148	144

Sensitivity= (42/148) = 28.4%
Specificity= (142/144).=98.6%

The positive LR=sensitivity/ (1–specificity)= 28.4/1.4 = 20.3
The negative LR=(1–sensitivity)/specificity=71.6/98.6 = 0.73

In clinical practice it is essential to know how a particular test result predicts the risk of abnormality.
Sensitivities and specificities do not do this: they describe how abnormality (or normality) predicts particular test results