Sensitivity and Specificity
A Caries Example

<table>
<tr><td>Sensitivity is a conditional probability; it is the probability that a diagnostic test is positive, given that the disease is truly present.</td><td>Specificity is a conditional probability; it is the probability that a diagnostic test is negative, given that the disease is truly absent.</td></tr>
<tr><td colspan="2">The term "given that" reflects that sensitivity and specificity are conditional probabilities
The <u>true</u> presence or absence of disease is measured by the best possible test one can come up with. This could be derived from autopsies, extracted teeth, or invasive, expensive or harmful diagnostic tests. Diagnostic test results are then evaluated against this gold standard. For instance, for caries the gold standard diagnosis could be histology. Teeth are extracted, microradiographs taken, and the presence/absence of caries determined. The gold standard diagnostic can be used to classify teeth or people in two groups; those with or without disease and to calculate sensitivity and specificity.</td></tr>
<tr><td>Calculating sensitivity
The sensitivity of a diagnostic test is the proportion of correct positive diagnoses in a diseased population. For instance, if 45 surfaces truly have caries and bitewing radiographs identify 24 out of the 45 lesions correctly, the sensitivity is 24/45 or 54%.</td><td>Calculating specificity
The specificity is calculated as the proportion of correct negative diagnoses in a non-diseased population. For instance, if 60 surfaces truly have no caries and bitewing radiographs identify 58 out of the 60 correctly, the specificity is 58/60 or 97%.</td></tr>
<tr><td colspan="2">Why are sensitivity/specificity meaningless statistics for a clinician?
When a clinician performs a diagnostic test, s/he does not know whether a tooth or individual has the disease or condition of interest. For instance, for caries, the available information is typically bitewings. Clinicians do not extract teeth to see if the bitewing information is accurate. The questions of interest for a clinician is:
1) What is the probability that a surface truly has caries, when the bitewing leads to a diagnosis of caries (a.k.a. the positive predictive value)?
2) What is the probability that a surface truly is sound, when the bitewing leads to a diagnosis of an absence of caries (a.k.a. the negative predictive value)?
.</td></tr>
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Sensitivity and specificity
A Caries Example

		Gold Standard (e.g., microradiography)	
		Caries	*No Caries*
Diagnostic test (e.g., bitewing)	*Caries*	**a (24)**	**b (2)**
	No Caries	**c (21)**	**d (58)**
		a+c (45)	**b+d (60)**

Sensitivity: a/(a+c) or 24/45 or ~0.54
Specificity: d/(b+d) or 58/60 or ~0.97

- Data adapted from J Dent. 1990 Jun;18(3):130-6. (**Mileman PA**, **van der Weele LT**.)
- For caries considered to be 'probably' in the dentin mean sensitivity was 54 per cent (s.d. 14 per cent) and specificity was 97 per cent (s.d. 5 per cent).

False Positive and False Negative Error Rates

What is the probability that a surface truly has early dentinal caries if you make such a diagnosis based on the bitewing information? This probability depends on something you do not know, namely the probability of early dentinal caries in your patient population. Intuitively, it may be clear that the higher this probability (e.g., caries level), the more likely a positive diagnostic test is a true positive. For instance, if every surface examined truly has caries, then every time a clinician classifies a tooth has having caries from the bitewing, the diagnosis will be correct. Conversely, the lower the disease probability, the more likely a positive diagnostic test (e.g., a caries lesion as diagnosed on a bitewing) is a false positive.

Now, if you had PROBABILITY 101 in college or high school, calculating the probability that disease is present, given that the test is positive is straightforward. For those who did not have PROBABILITY 101 (or forgot that they had it) it is also relatively straightforward (Phhhhewwww).

Calculating false positive and false negative error rates.

Step 1: Assume the probability of early dentinal caries in your Bellevue practice is 0.3%. That means for every **10,000** surfaces you examine on your bitewings (250-500 patients), 30 will truly have caries. Thus, if you could extract the teeth and do the histology on the surfaces, you would come to the conclusion that 30 surfaces truly do have caries.

		microsection		
		Caries	*No Caries*	
bitewing	*Caries*	a	b	
	No Caries	c	d	
		a+c= 30	b+d = 9970	**10,000**

Step 2: Complete the 2x2 table sensitivity (0.54) and specificity (0.97)

		microsection		
		Caries	*No Caries*	
bitewing	*Caries*	a=> 30*0.54=16	B	
	No Caries	C	D=> 9970*0.97 =9671	
		a+c (30)	b+d (9970)	**10,000**

Step 3 Fill in "c" and "b" by simple subtraction

		microsection		
		Caries	*No Caries*	
bitewing	*Caries*	16	b=>9970-9671=299	
	No Caries	c=> 30-16=14	9671	
		a+c (30)	b+d (9970)	**10,000**

Step 4: Calculate the number of positive and a negative test results with bitewings by adding the row entries.

		microsection		
		Caries	*No Caries*	
bitewing	*Caries*	16	299	16+299=315
	No Caries	14	9671	1+967=9685
		a+c (30)	b+d (9970)	**10,000**

In this example, with caries probability of 30/10000, you would conclude, based on the bitewings, that there are 315 dentinal cavities. However, only 16 of these 315 cavities are truly cavities as diagnosed by histology. The **false positive error rate** is 299/315 or 95%. The **positive predictive value** is 1 – 0.95 or 0.05. For every 100 diagnoses of dentinal caries, 95 would be histologically sound surfaces and 5 on early dentinal caries lesions.

Similarly, 9685 times the bitewing would lead to the conclusion of no caries. However, for 14 surfaces this would be a false negative and the **false negative error rate** is 14/9685 or 0.001. The negative predictive value is 1 – 0.001 or 0.999.

False positive and false negative error rates
Positive and Negative Predictive Value

		microsection		
		Caries	*No Caries*	
bitewing	*Caries*	16	299	16+299=315
	No Caries	14	9671	14+9671=9685
		a+c (30)	b+d (9970)	**10000**

The following statistics can be derived from this 2x2 table

a) Prevalence of disease: 30/10,000 = 0.3%
b) Sensitivity; 16/30 or 0.53
c) Specificity; 9671/9970 or 0.97
d) False positive error rate; 299/315= 0.95
e) Positive Predictive Value; 16/315=0.05
f) False negative error rate; 14/9685=0.001
g) Negative predictive value; 9671/9685=0.99

How can false positive and false negative error rates be reduced?

The more subtle the disease or condition, the higher the error rates. For instance, the more advanced the caries lesion, the easier it is to diagnose. One does not need a bitewing radiograph to determine whether there is a D3 lesion on the approximal surface of a tooth. What is more challenging is to diagnose the presence/absence of early enamel lesion or early dentinal lesions.