This appendix is the first half of the presentation we did for version 1, with M&Ms and skittles where the students do the calculations for two different prevalences. The slides have a black box around them. When appropriate, the text outside and following the box provides additional information about the slide.

**Scenarios to motivate the activity.**

Imagine you are on a committee that has to decide who gets tested for Covid19. The choice is to test everyone or only test those that have symptoms or have a known contact with someone who has the infection. In this activity we will learn about some of the trade-offs of whether it is more important to reduce false positives or false negatives.

Imagine someone has suggested that all students at a university should be tested for STIs in order to reduce the stigma for getting an STI test. Another person argues that only those at high risk should be tested. In this activity we will learn about some of the trade-offs of whether it is more important to reduce false positives or false negatives.

Screening for some cancers, e.g., breast, prostate and colon cancer, is recommended depending upon one’s age. In this activity we will learn about some of the trade-offs of whether it is more important to reduce false positives or false negatives.

We provide these scenarios to motivate the student by showing them the relevance of understanding the topics in this activity.

When doing a test, there are 2 types of people: those that have the condition and those that don’t. There are also 2 possible outcomes: test is positive and test is negative.

Can you label the 4 categories of people we should consider across these conditions?

When we did this online, we had the students write down their answers to the questions in the pink rectangles along with the slide number. In these slides, we often show the answer on the slide that asks the question. Note: One has to be a bit careful with the smiley and frowny face because for different people, M&M’s or Skittles may be desirable.
Note: We feel it helpful for the students to first develop their own terms for these categories before hearing the “official” terms. Oftentimes, the authors themselves had to pause and think about what true positive refers to in these activities. (Here true positive is a red M&M, in Appendix 2, a true positive is a small marble; in Appendix 3, a short female is a true positive.)
After the students write down their answers, we show them the correct answers.

In the activity, the test is whether the candy is red (positive) or not red (negative). The condition is “being an M&M” and not having the condition is “being a skittle.”

Stated another way:

- Red is a positive test,
- not red is a negative test.
- M&M have the condition,
- Skittles do not have the condition.
As the students will see, this particular layout helps to organize which values are used to calculate each of the four parameters.

Answering the question about true positive, etc., with these items really helps the students grapple with what the terms mean.
Here are the answers.

Sensitivity-
how well does the test detect people with the condition

Specificity-
How well does the test determine people that do not have the condition

Positive predictive value (PPV)-
What are the odds if one has a positive test that one has the condition

Negative predictive value (NPV)-
What are the odds if one has a negative that one does not have the condition

We have tried to first discuss the ratios and then give the official terms, but referring to the first calculation, second calculation, etc. seemed unnecessarily clumsy.
They will be filling in the values on this table in the next segment of the activity.

|                  | First example | Second example | Third example |
|------------------|--------------|---------------|--------------|
| Sensitivity      |              |               |              |
| Specificity      |              |               |              |
| Odds M&M if red (PPV) |            |               |              |
| Odds Skittle if not red (NPV) |          |               |              |

The first characteristic is called sensitivity, how many of the people with the condition have a positive test. For our case a positive test is red and the condition is being an M&M.

What fraction of the M&Ms are red?

Or more generally, **Sensitivity-how well does the test detect people with the condition?**

If you find out that you got the wrong answer, that is ok. But do not change your answer. **Put answer into table.**

We deliberately help them out here-giving them both the general definition of sensitivity and also the specific definition with the candies.
It is not important for the students to reduce the fraction or convert it to the decimal form as we are more interested in them understanding which ratio is used to calculate sensitivity. However, the reduced fraction or decimal form are easier to compare, so we provided that to them.
The second calculation is the specificity, what fraction of people without the condition test negative. For our case a positive test is red and the condition is being an M&M. What fraction of the skittles are not red? Put answer into table.

The second calculation is the specificity, which what fraction of the skittles are not red.

\[\frac{10}{12} = \frac{5}{6} = 0.83\]
The third calculation what is the positive predictive value or the odds that if a candy is red, that it is an M&M. For our case a positive test is red and the condition is being an M&M. What are the odds that if a candy is red, that it is an M&M. 

Put answer into table.

\[
\begin{array}{cccc}
M & M & M & M \\
M & M & M & M \\
M & M & M & M \\
M & M & M & M \\
M & M & M & M \\
M & M & M & M \\
M & M & M & M \\
M & M & M & M \\
S & S & S & S \\
S & S & S & S \\
S & S & S & S \\
S & S & S & S \\
S & S & S & S \\
\end{array}
\]

The third calculation what are the odds that if a candy is red, that it is an M&M.

\[
\frac{20}{22} = 0.91
\]
The fourth calculation is what are the odds that if a candy is not red, that it is a skittle?

Put answer into table.

\[ \frac{10}{14} = 0.71 \]
This appendix is the second half of the presentation we did for version 1, with M&Ms and skittles where the students do the calculations for two different prevalences. The slides have a black box around them. When appropriate, the text outside and following the box provides additional information about the slide.

|                      | First example | Second example | Third example |
|----------------------|---------------|----------------|---------------|
| Sensitivity          | 20/24=5/6 = 0.83 |                |               |
| Specificity          | 10/12=0.83    |                |               |
| Odds M&M if red (PPV)| 20/22=0.91    |                |               |
| Odds Skittle if not red (NPV) | 10/14=0.71 |                |               |

For the format we chose for laying out the candy, the first column values are used to calculate sensitivity and the second column, specificity.
The top row values are used to calculate positive predictive value and the bottom row, negative predictive value.

After doing the columns and rows separately, we then show this busier slide that has all 4 values.
Now we are going to change the amounts of some of the candies. I will use a gray rectangle to “cross out” some of the candies and also use the gray to cover up the original number. What is the sensitivity, of those that have the condition, how many test positive? Do NOT put answer into table.

For the next calculation, we are going to change prevalence and have the students repeat the calculation to see how prevalence changes some of the parameters.

The first calculation, sensitivity, which is what fraction of the M&Ms are red involves the red M&Ms and it changes from 5/6 to 3/5 (0.83 to 0.5).

\[
\frac{20}{24} = \frac{5}{6} = 0.83
\]

\[
\frac{5}{9} = 0.55
\]
If the students are stuck, we suggest a problem-solving approach to make a guess and see what happens. There are only 4 obvious guesses—either increase or decrease the number of red and either increase or decrease the number of non-red. They can start by removing one candy from their group and determine whether they are getting closer to \(5/9\). (Decimals may help here, so using their phone to calculate is encouraged.) They will then figure out that the simplest answer is to reduce the number of non-red M&Ms by 3 and also begin to appreciate how guesses can help them solve a problem they are stuck on as shown in the slide below.

Now if we change both terms (red M&Ms and non-red M&Ms) the first calculation, sensitivity, does not change.

\[
\frac{20}{24} = \frac{5}{6} = 0.83
\]

\[
\frac{5}{10} = \frac{1}{2}
\]

\[
= 5/6 = 0.83
\]
They then enter the value into the table.

|                  | First example   | Second example | Third example |
|------------------|-----------------|----------------|---------------|
| Sensitivity      | 20/24=5/6 = 0.83| 5/6=0.83       |               |
| Specificity      | 10/12=0.83      |                |               |
| Odds M&M if red (PPV) | 20/22=0.91 |                |               |
| Odds Skittle if not red (NPV) | 10/14=0.71 |                |               |

We give them some time to ponder this question. For those that are stuck, they can try the four calculations and see what happens, but we think it would be better if they think about the ratios and which ratios involve the gray crossed out area.
When we change prevalence, what two characteristics change?

It should be clear that the first calculation, sensitivity, involving the two left characteristics do not change. Also, the second calculation, specificity, involving the two right characteristics does not change.

When we change prevalence, what two characteristics change?

But both the third and fourth calculations do change! These are positive predictive value and negative predictive value.
By having them do the calculation (and translating the general definition to the specific case) we are giving them more practice and familiarity with the concepts and definitions.

Calculate the new positive predictive value (odds if positive that you have condition) and new negative predictive value (odds if negative you do not have the condition).
You might find it helpful to reword the question in terms of M&Ms vs. skittles and red vs. non-red).
The third calculation which is what are the odds that if a candy is red, that it is an M&M or positive predictive value changes from 0.91 to $5/7$ (0.71)

$\frac{20}{22} = 0.91$

$\frac{5}{7} = 0.71$

The fourth calculation or negative predictive value, is what are the odds that if a candy is not red, that it is a skittle?

$=\frac{10}{14} = 0.71$

$=\frac{10}{11} = 0.91$
By having them do the calculation (and translating the general definition to the specific case) we are giving them more practice and familiarity with the concepts and definitions.

|                        | First example | Second example | Third example |
|------------------------|---------------|----------------|---------------|
| Sensitivity            | 20/24=5/6 = 0.83 | 5/6=0.83       |               |
| Specificity            | 10/12=0.83    | 10/12=0.83     |               |
| Odds M&M if red (PPV)  | 20/22=0.91    | 5/7=0.71       |               |
| Odds Skittle if not red (NPV) | 10/14=0.71 | 10/11=0.91     |               |

Going from the first to the second example, the prevalence decreased. How does that change the odds of being an M&M vs. being a skittle when sensitivity and specificity do not change?

Now repeat the process, but this time drop the number of red skittles in half.
What else do you have to change so that sensitivity and specificity do not change?
And then how do the PPV and NPV change?
We finish by having them come back to the opening scenarios. The class can vote to discuss one scenario, the students can be divided into groups to discuss their most interesting scenario, or, if there is time, all 3 scenarios can be discussed. Doing the latter really helps them understand the different trade-offs depending upon what is being tested. For example, false negatives have very different consequences for the 3 scenarios.

|                | First example | decreased prevalence | Third example |
|----------------|---------------|----------------------|---------------|
| Sensitivity    | 20/24=5/6 = 0.83 | 5/6=0.83             | 20/24=5/6 = 0.83 |
| Specificity    | 10/12=0.83    | 10/12=0.83           | 5/6=0.83      |
| Odds M&M if red (PPV) | 20/22=0.91    | 5/7=0.71             | 20/21=0.95    |
| Odds Skittle if not red (NPV) | 10/14=0.71    | 10/11=0.91           | 5/9=0.56      |

In the third example, the prevalence increased compared to the first example. How does that change the odds of being an M&M vs. being a skittle when sensitivity and specificity do not change?

As prevalence increases, the odds of a positive test being correct INcreases and the odds of a negative test being correct DEcreases