<u>Activity Guide:</u>

Segment 1: Video segment is 1 minute 30 seconds. Pause time is 1-2 minutes for the following activity:

The students discuss and write down their guesses for: "Which of these answers is closest to the number of bacteria that are living on or in a single human being?" The teacher can (1) write the options a-d on a blackboard or piece of paper in the front of the class to keep a public tally of the students' guesses, (2) have the students vote by raising hands for each answer a-d, or (3) have students write down their answers on their own paper, in silence. The answer will be revealed in the next video segment.

Segment 2: Video segment is 4 minute and 35 seconds. Pause time is 8-12 minutes for the following activity:

Pass out the "Testing bacterial growth" handout (the same handout for each student), which shows sample 'plates' with different amounts of bacterial growth on them. Discuss with the students the results of the negative & positive control samples, which are labeled:

> Controls (these plates are labeled on the handout):
> -nothing added to the plate (negative control): the students should note that the plate is smooth: there is nothing growing on the plate
> -lab-cultured bacteria (positive control)" the students should note that the plate has speckles and swirls present: these are bacteria growing

Have students predict which plates go with which samples by writing in their prediction for the sample name next to each plate, choosing from the list of samples that were tested. The teacher can choose whether to encourage the students to discuss their answers or instead work independently. The teacher should go through the correct answers with the students during the break and discuss them:

> Answers for the remaining, unlabeled samples:
> *Plate 1* -> swab from wound of a patient at the hospital with an infection (students should note heavy growth of white-colored bacteria across most of the plate – there are so many bacteria that distinct colonies are not visible but instead the bacteria cover most of the plate)
> *Plate 2* -> boiled water (students should note that the plate is smooth with no bacteria growing. Boiling water is an effective way to kill bacteria.
> *Plate 3* -> swab from wound of a patient at the hospital with an infection + antibiotic (students should note the heavy growth of white-colored bacteria across most of the plate, but also that the tablets of antibiotic are killing bacteria in a zone around each tablet. The teacher might ask the students about why the regions around the tablets have no growth (the antibiotic is diffusing out of each tablet) and why the zones might be different sizes (perhaps they are different types of antibiotics – some more effective than others, or perhaps they are different dosages, or perhaps some are wetter than others and diffuse better, for example).
> *Plate 4* -> fingerprints after washing hands (there are a few colonies of bacteria, but not as many as plate #6. Still, washing hands does not completely eliminate bacteria, so there are more colonies than plate #2.)
> *Plate 5* -> water from a roadway (lots of bacteria are found in unboiled water)
> *Plate 6* -> someone's fingerprints in the middle of the day (the pattern of bacterial colonies, clustered into regions that correspond to fingers, are a clue that these are fingerprints)

The next video segment moves on to the next topic, so the teacher should discuss the results above thoroughly with the students, focusing on developing the students' reasoning skills.

Segment 3: Video segment is 3 **minutes and 35 seconds. Pause time is** 3-5 **minutes for the following activity:**
For the "Chemical Structures" activity, give each student (or group of students) a different printed-out chemical structure on paper. The teacher should keep the 3 negative controls (water) and 3 positive controls (Rifampicin). Instruct the students to guess whether their chemical is a natural product or a synthetic chemical – you could discuss ideas for how to tell the difference, but keep in mind that these really are guesses – it is not usually obvious whether a chemical is natural or synthetic! This conundrum will be discussed in the next video segment. Go through the answers with the students, using the answers provided as a separate document.

Segment 4: Video segment is 2 minutes and 24 seconds**. Pause time is** 2-4 **minutes for the following activity:**
Discuss with the students this question: If we find a chemical that kills bacteria, should we immediately begin giving it to patients to try to cure their infections? What might be a problem if we do that? Potential answers might be: it might kill the patients, because a chemical that kills bacteria might also kill human cells. It might also cause side effects that make the chemical intolerable for humans. Another answer is that we should first carefully test what dosage of chemical to give to humans. Only the first answer is mentioned in the next video segment, so be sure to encourage the class to think up and discuss several possibilities before resuming the video.

Segment 5: Video segment is 5 minutes and 25 seconds. Pause time is 3-5 **minutes for the following activity:**
The teacher (or the students) should perform the sample preparation as described (probably with the students helping), using a cup for each sample:

1. In advance of the class session, lay out and label the 36 cups to match the drawing of the 36-well plate on the board (the "Lab Notebook").
2. Add the same number of "human cells" into each cup (the teacher might emphasize the importance of consistency by counting cells as they are placed, or by measuring the cells going into each sample).
3. Add the same number of "bacteria" to each cup.
4. Invite the students to write in one of the wells of the "Lab notebook" their chemical's name (that is, the chemical whose structure they examined in Segment 3's activity), then have the student put their "chemical" (that is, the five pieces of paper torn off of the bottom of the "Chemical Structures" handout that represent the chemical) into the corresponding cup. The teacher can demonstrate this by taking the three negative and three positive control "Chemical Structures", writing their location in the "Lab notebook", and placing them into the corresponding six cups. Any chemical can go in any cup, as long as good records are kept.
5. Once all of the cups have a control or test sample chemical added to them, the teacher should pretend to incubate the samples, perhaps by moving them elsewhere in the room, or putting a cloth over the samples during the next video segment. In the real experiment, the incubation time is 3-5 days.

Once the samples are prepared and "incubating", return to the video.

Segment 6: Video segment is 2 **minutes. Pause time is** 8-12 **minutes for the following activity:**
The teacher should pretend to take images of each of the 36 samples and give each student (or group of students) an "Identifying new antibiotics" handout, as if it resulted from the image that was taken for their particular chemical(s). There is no need to match a particular "Identifying new antibiotics" handout with a particular "Chemical structures" handout for the purposes of this demonstration, with an exception: the teacher should keep the 6 handouts corresponding to the negative and positive controls (3 of each). In other words, the activity has not been set up to yield actual experimental results – so be prepared: depending on how you randomly hand out the "Identifying new antibiotics" handouts, the experiment might yield some silly answers, like aspirin being a good treatment for tuberculosis! Reassure the students that the results from doing this experiment activity are not "real", so random chance is determining the outcome, to keep it interesting.

The teacher should then guide the students through the scoring of the images in the "Identifying new antibiotics" handouts they received, as described in the previous video segment:

(1) Count the number of bacteria (small, solid, dark shapes) and record the number in the proper place on the handout – students might be uncertain about whether to count very small, faint objects. Encourage them to discuss amongst themselves how to score faint objects: the most important thing is to be consistent in their scoring so that all samples are scored fairly.

(2) Count the number of human cells (lined objects) and record the number in the proper place on the handout

(3) Score the human cells in the range of 1-10: give the sample a higher number if most of the human cells are round and a lower number if there are many cells with irregular shapes. This is the most confusing step, because of course it is difficult to judge how "round" a collection of cells in order to assign it a single number. Encourage the kids to make their best guess/judgment and perhaps compare their answers with other students to try to "calibrate" what they consider "round" with others in the class.

Then, have the students copy the three scores for the image on their "Identifying new antibiotics" handout to the "Lab notebook". Interpreting those scores to identify which chemicals are worth pursuing is the topic of the next video segment.

Segment 7: Video segment is 45 seconds. Pause time is 3-5 **minutes for the following activity:**
The teacher should guide the students to discuss which chemicals are potentially good antibiotics (there should be roughly 5 samples that yield somewhat successful results according to the criteria: few bacteria, many human cells, normal human cell shape). Remember, there is no obviously perfect chemical. The students should discuss and debate which criteria are most important and which should be weighted most heavily (bacteria count, human cell count, vs. human cell shape). Remember, the results are not real, because the images were randomly assigned to a chemical sample – this is because the real experiment is still in progress!

Segment 8: Video segment is 30 seconds. Pause time is 2-4 **minutes for the following activity:**
The teacher should guide the students to discuss what problems would arise if they needed to score a million samples by examining them, as they just did. Potential answers: (a) Very slow - perhaps have the students roughly calculate how long it would take their class to score 1,000,000 samples at the pace they just accomplished, (b) inaccurate/subjective – scoring images by examination is subjective and error-prone. Different people might have different opinions about how to score the shape of the human cells, and their judgment might change from the

beginning of the day to the end of the day as they get tired. Counting bacteria is also fairly subjective, (c) tedious and boring! It would be difficult to hire someone willing to score images by examination all day, every day.

Segment 9: Video segment is 1 minute and 50 seconds. This concludes the lesson.

Teacher video guide: Video segment is 5 minutes and 20 seconds and it discusses an overview of the lesson and activities, as well as other resources the teacher might want to explore to expand on the lesson. The websites mentioned are:

Software:

CellProfiler software: http://www.cellprofiler.org

Scratch software: http://scratch.mit.edu

Bacterial growth experiment (testing everyday samples for bacterial growth on plates)**:**

Websites with lesson plans:

Howard Hughes Medical Institute's virtual lab on culturing every day bacteria (does not require plates and agar materials)
http://www.hhmi.org/biointeractive/disease/vlab.html

Culturing every day bacteria:
http://www.chicagotribune.com/news/opinion/letters/ny-nw-biology-lesson,0,4489207.story

Culturing microbes that produce antibiotics
http://www.waksmanfoundation.org/labs/cornell/microdis.html

Sources for materials (copy the long addresses onto a single line in your web browser):

http://www.bio-rad.com/prd/en/US/adirect/biorad?
ts=1&cmd=BRCatgProductDetail
&vertical=LSE&catID=2842659f-0c53-4fb6-bf84-0cc6daa70baf#

http://www.carolina.com/category/life+science/
biotechnology+kits+%26+materials/culture+media.do

http://www.sciencebuddies.org/science-fair-
projects/project_ideas/MicroBio_Agar.shtml#AgarPrep