Figure S1

Question 21: **List 5** safety concerns illustrated in this image

Figure Q21
(original picture from http://katfix.livejournal.com/36218.html)

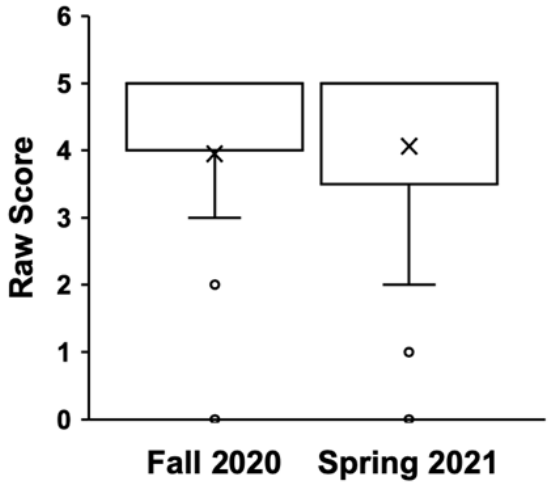


Figure S2. Box-and-whisker graph of the Streak Plate scores for each semester examined. The (X) in the box represents the average score of the class, while the horizontal line in the box represents the median score. Outliers are shown as open dots. This assignment had a maximum value of 5 points.

Online Microbiology Student Budget

Table S1. Reagent cost from distributor

Item	Number	Description	Cost	Link
Microscope	1	AmScope 120X-1200X 52-pcs Kids	$41.99	https://amscope.com/products/c-m30-abs-kt2
Bacteria Growing Kit	1	125 ml bottles of Nutrient Agar and other materials	$32.95	https://www.homesciencetools.com/product/bacteria-growing-kit/
Gram Stain Kit	1	Kit containing slides and Gram St	$24.95	https://www.homesciencetools.com/product/gram-stain-lab-kit/
Inoculating loop	1	Inoculating needle with looped en	$4.15	https://www.homesciencetools.com/product/inoculating-needle-looped-end/
			$104.04	

Table S2. Estimated student cost.

Item	Number	Description	Cost**	Link
Lab coat*	1	Lab coat	$16.99	https://www.amazon.com/NY-Threads-Professional-Laboratory-CoatKick/dp/B08VDZ6KCT/ref=sr_1_1_sspa?crid=2IY3N5R5IJQSN&keywords=lab+coat&qid=1646262874&sprefix=lab+coat%2Caps%2C128&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyQk1KU1E0S0hZUzgyJmVuY3J5cHRlZElkPUEwNDU0OTc5MjlFT1FLMldKNE44RiZlbmNyeXB0ZWRBZElkPUEwMTk0NzA4M1JDSERRTThlVlBDTyZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tDZkb05vdExvZ0NsaWNrPXRydWU=
Safety Googles*	1	Protective Saftely Lab Googles	$12.99	https://www.amazon.com/Supermore-Anti-Fog-Protective-Safety-Goggles/dp/B07VF3C2CW/ref=sr_1_2_sspa?keywords=safety+goggles+students&qid=1646262930&sprefix=safety+goggles+studen%2Caps%2C139&sr=8-2-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzRkZRV1pUWk45SVoxJmVuY3J5cHRlZElkPUEwMDM3MzUzTVJaME5QOE1HVTZYJmVuY3J5cHRlZEFkSWQ9QTAwMzc2OTUxU0JXNEtCM003WUtCJndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==
Lab notebook	1	Composition notebook to record e	$9.74	https://www.amazon.com/AmazonBasics-College-Composition-Notebook-100-Sheet/dp/B07D2QPXM8/ref=sr_1_1_sspa?crid=3C66XHVN2XNRL&keywords=composition+notebooks&qid=1646263872&sprefix=composition+not%2Caps%2C132&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFUQzBGQ1c5SUs0QTMmZW5jcnlwdGVkSWQ9QTAxNDIwMzExTDg2TkgwNjMzUlU3JmVuY3J5cHRlZEFkSWQ9QTAyODkyMzgxVlNGRElNTlBDUiZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdENsaWNrPXRydWU=
nitrile gloves	1	Powder-free nitrile exam gloves	$14.79	https://www.amazon.com/MedPride-Powder-Free-Nitrile-Gloves-Medium/dp/B00GS8W3T4/ref=sr_1_3?crid=2DG6T94FBRJOU&keywords=nitrile+gloves&nav_sdd=aps&qid=1646262991&refinements=p_n_size_two_browse-vebin%3A11348606011&rnid=11348603011&s=industrial&sprefix=nitri&sr=1-3
			$54.51	

***Most students have these materials from Previous classes. Cost based on Amazon.com prices.**

****Cost based on Amazon.com prices.**

Table S3. Course deliver Cost per student for each course

Items	#Students	Cost/student	Cost/Class
Fall 2020			
Reagents	40	$104.04	$4,161.60
Labster*		$20	$800
Total		$124.04	**$4,961.60**
Spring 2021			
Reagents	41	$104.04	$4,265.64
Labster*		$20	$820
Total		$124.04	**$5,085.64**

* Labster cost based on the highest cost per student under the Institutional License.

Supplemental Material 1

The in-person and online General Microbiology Laboratory classes had the same Course Learning Objectives.

Course Learning Objectives: In addition to the course objectives encompassed in the General Microbiology Lecture, this laboratory class will allow our student to:

1) utilize microbiological laboratory techniques to isolate, identify and characterize microorganisms.
2) discern the molecular, metabolic, and structural differences between microbial cells and how these differences allow scientist to utilize microbes as tools for science, medicine, and industry.
3) gain the laboratory experience to perform laboratory research and maintain a laboratory notebook following Good Laboratory Practice techniques.
4) work with numerical data, including the calculation of bacterial doubling times, generations, and growth rates, as well as dilution factors.
5) exercise procedures to ensure safety in the laboratory.

Supplemental Material 2

Use Labster as well as other simulations to provide students with virtual laboratory experiences.

Labster Simulations Used

1. Lab Safety
2. Biosafety
3. Bacterial Isolation
4. Microscopy
5. Gram Stain
6. Bacterial Cell Cultures
7. Identification of Unknown
8. Bacterial Quantification by Culture
9. Bacterial Growth Curves
10. Cell Membrane and Transport
11. Fermentation
12. Cellular Respiration
13. Electron Transport Chain (Photosynthesis)
14. Polymerase Chain Reaction
15. Genetic Transfer in Bacteria
16. Next Generation Sequence
17. Control of Microbial Growth
18. Pasteurization and Sterilization

Other Simulations Used:

Streak plate technique:
http://learn.chm.msu.edu/vibl/content/streakplate.html

BioInteractive Bacterial Identification Lab
https://www.biointeractive.org/classroom-resources/bacterial-identification-virtual-lab

Simulation no longer supported after the retirement of Adobe Flash Player:

Microscopy
http://virtual.itg.uiuc.edu/training/LM_tutorial/

Growth as a function of temperature lab
http://virtuallaboratory.colorado.edu/BioFun-Support/labs/GrowthLab/OnGrowth.html

Class Zone Bacterial Transformation simulation
http://www.classzone.com/books/hs/ca/sc/bio_07/virtual_labs/virtualLabs.html

Supplemental Material 3

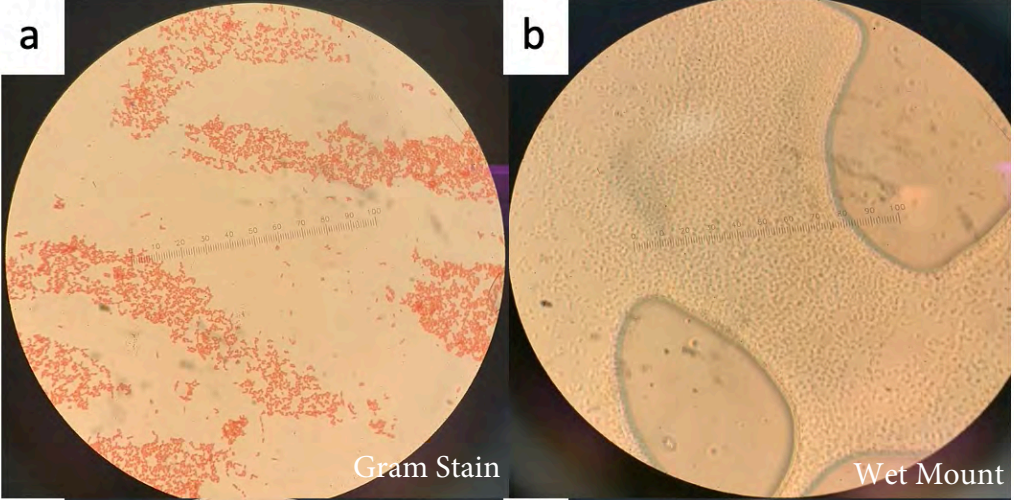
Link to the Streak Plate Video, a sample of one of the videos used in class to teach lab techniques.

https://youtu.be/R2rLBUmBBx4

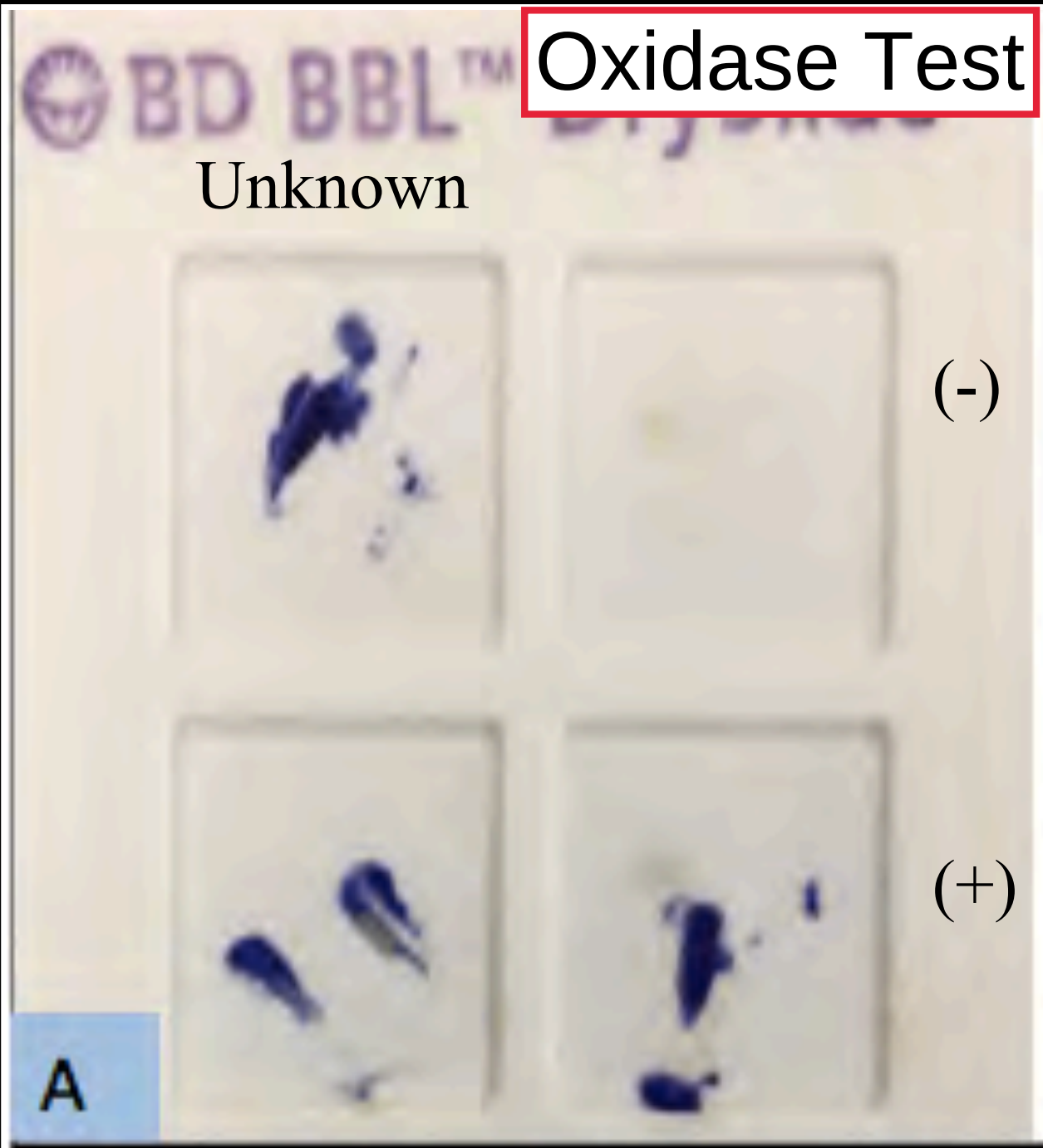
Supplemental Material 4

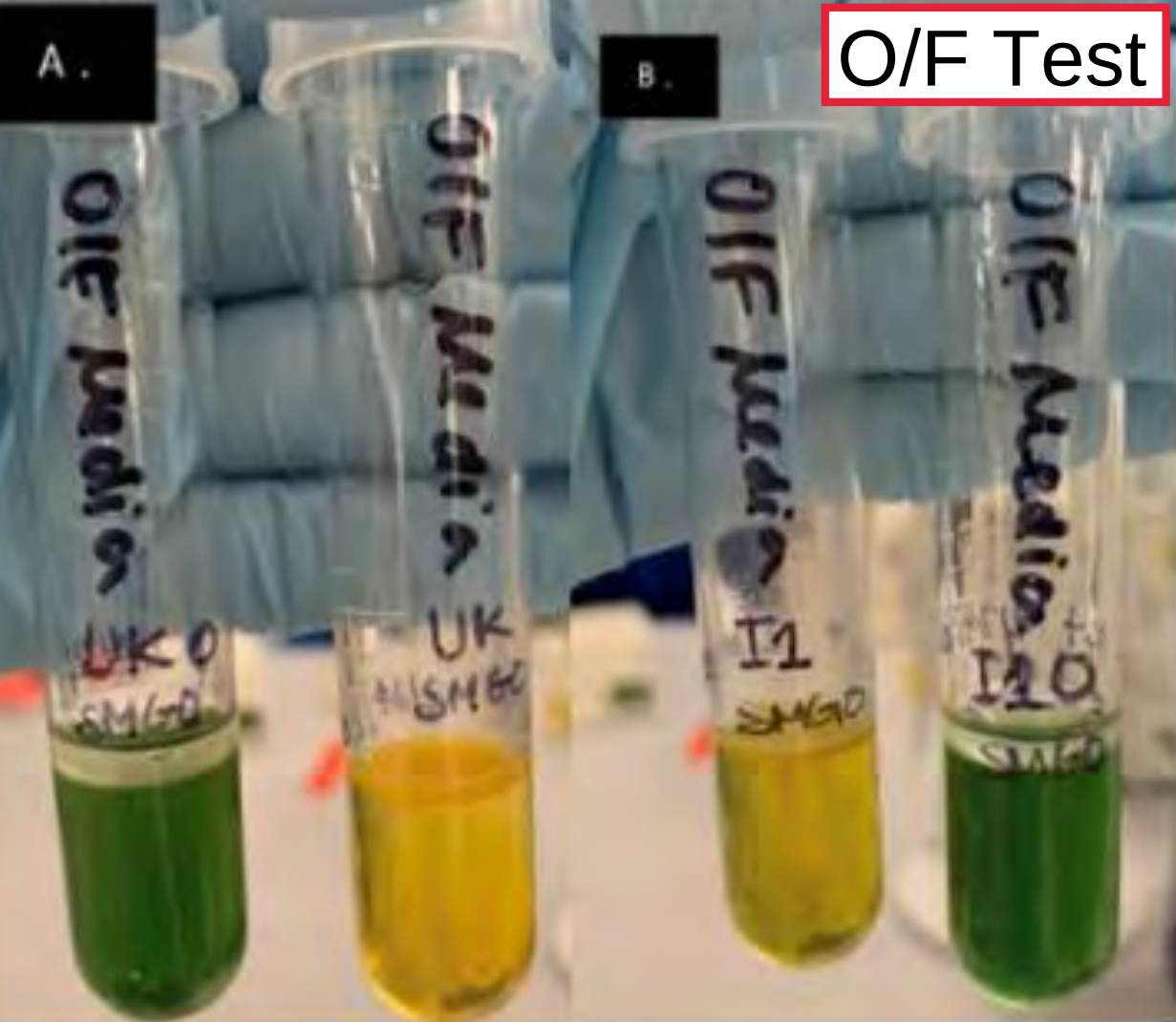
Unknown Portfolio 1A

(P. aeruginosa)


a
Gram Stain
b
Wet Mount

Oxidase Test

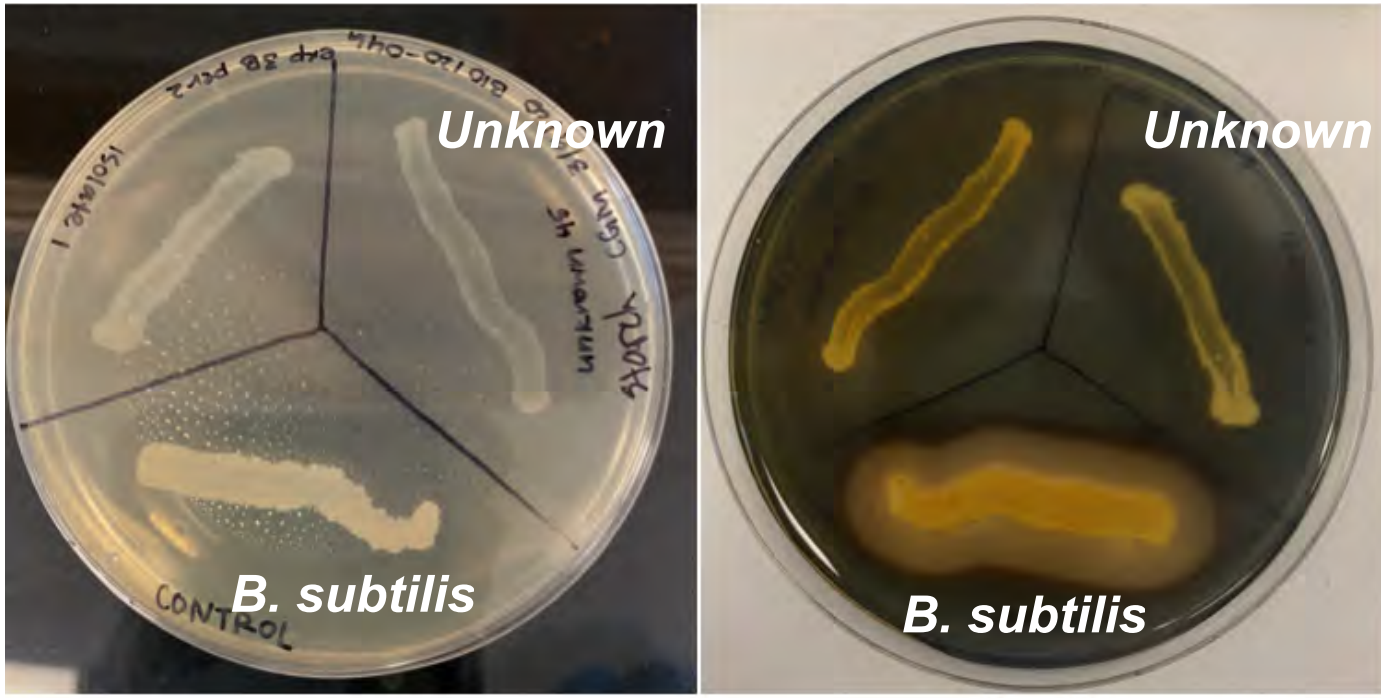



A.
B.
O/F Test
O/F Media
UK
O
SMGO
O/F Media
UK
SMGO
O/F Media
I1
SMGO
O/F Media
I1
O
SMGO

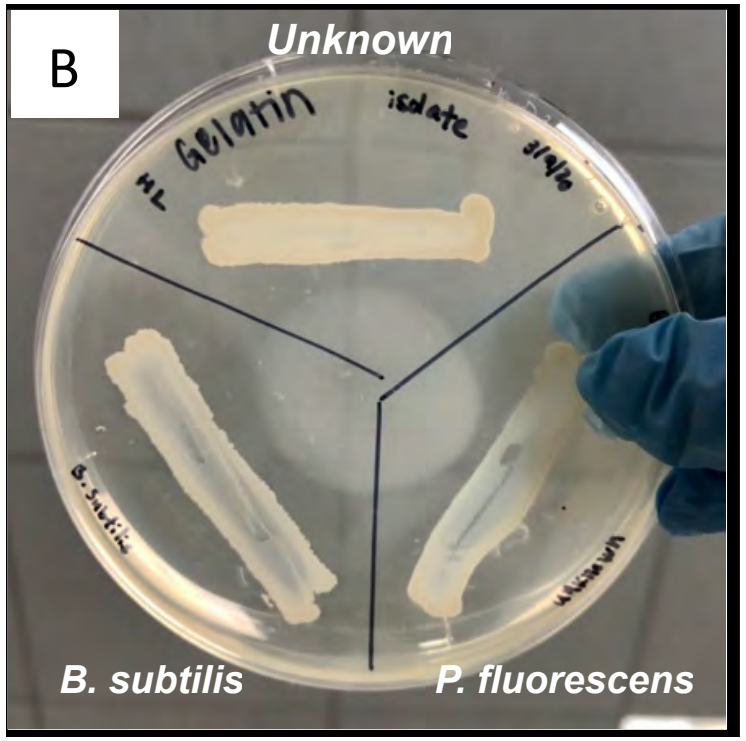
Supplemental Material 4
Unknown Portfolio 1B
(*P. aeruginosa*)

Catabolic Analysis

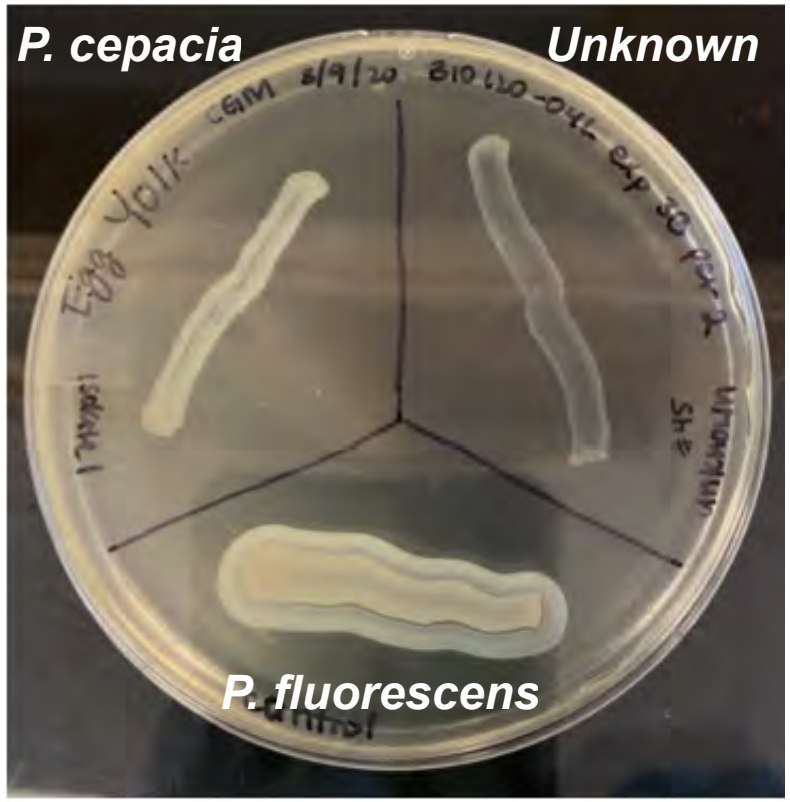
OD_{600} readings of 24h culture of unknown bacteria in MSA media supplemented with 0.1% Carbon source							
	OD600						
MSA	0.005						
acetamide	0.53						
maltose	0.17						
lactose	0.005						
fructose	1.355						
glucose	1.475						
p-hydroxybenzoate	1.43						
glycine	0.875						
nicotinate	1.175						
geraniol	0.68						
tryptophane	0.815						
YTA	1.505						
MSA and YTA plates used as controls							



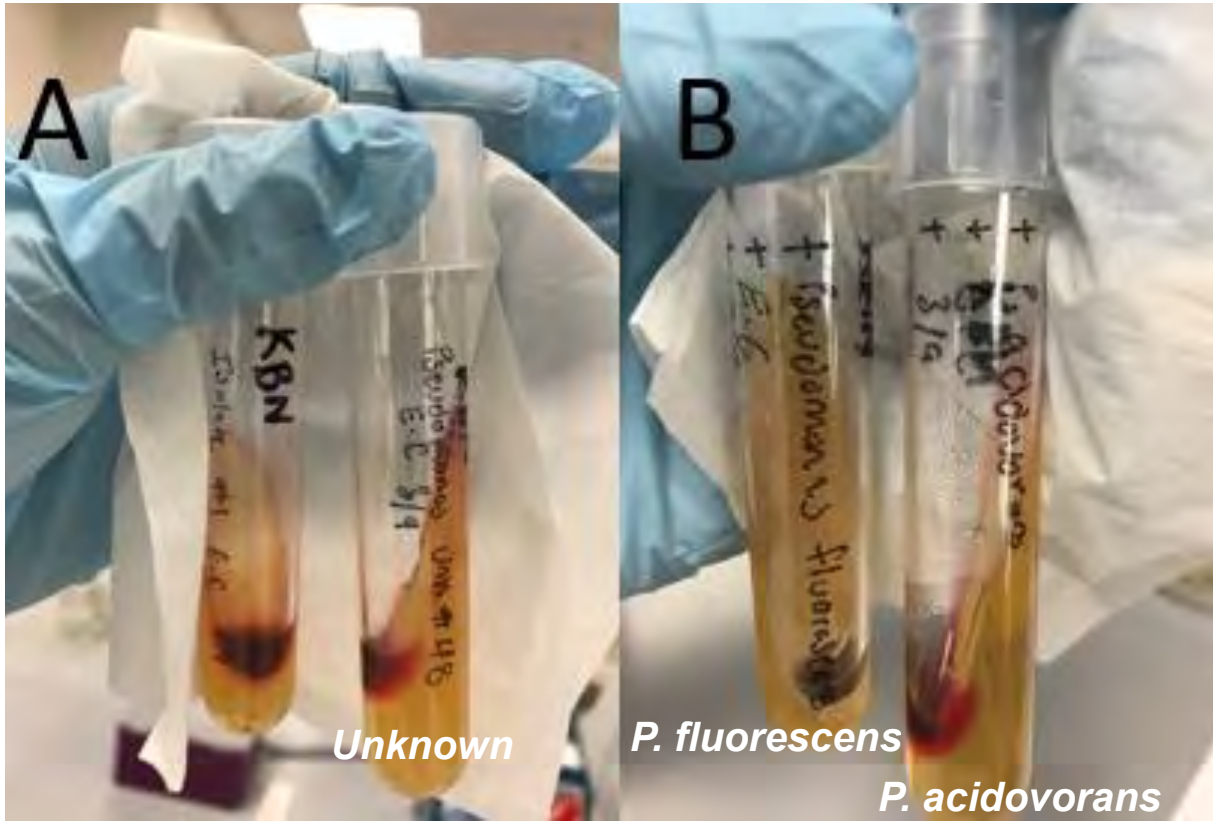
Starch Hydrolysis



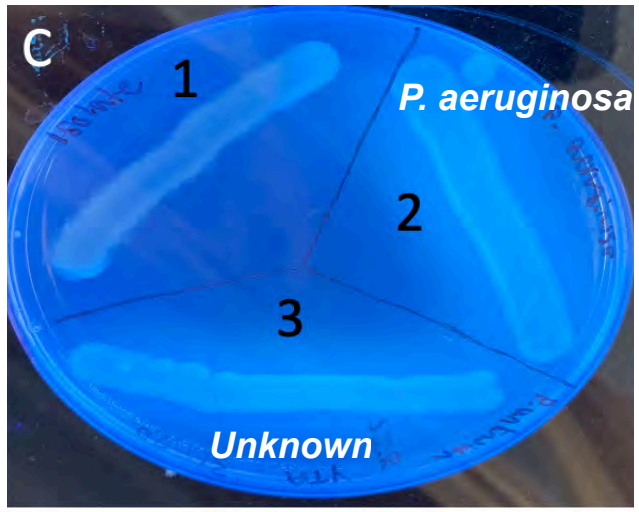
Gelatin Hydrolysis

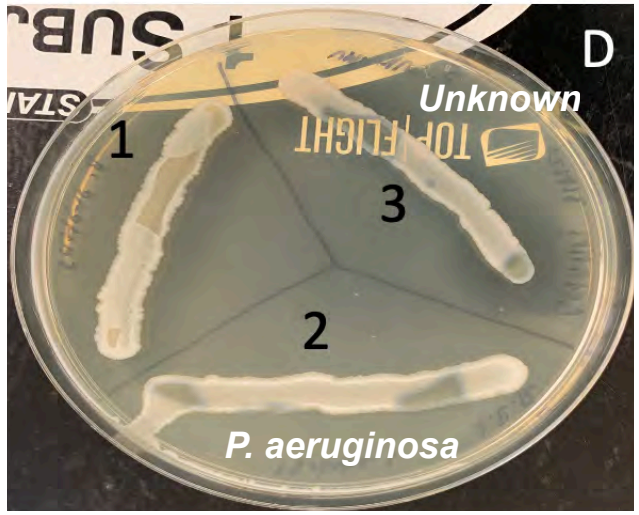


Egg Yolk (Lecithinase)

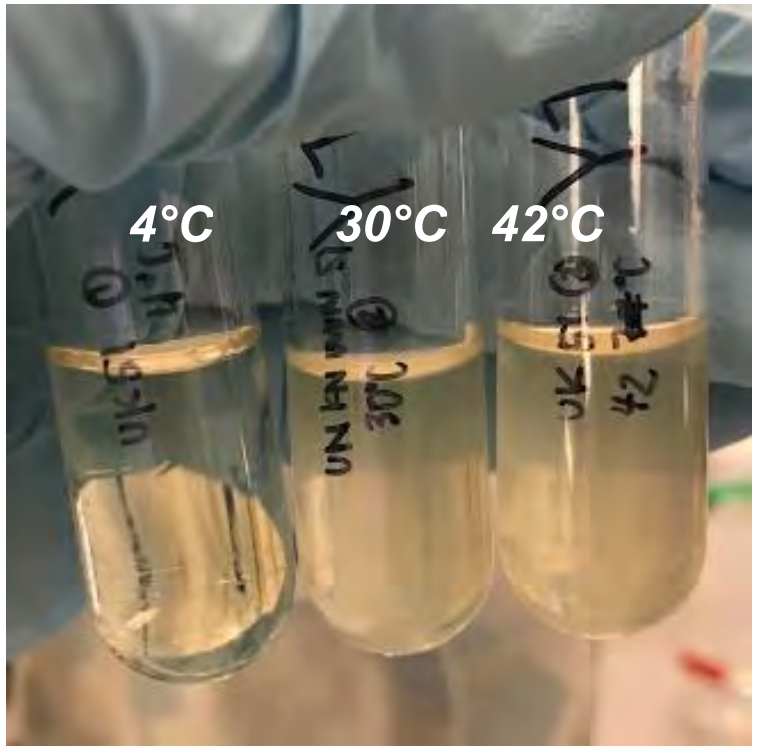


Nitrate Reduction





Pigment Production



Growth at Various Temperature

Supplemental Material 5

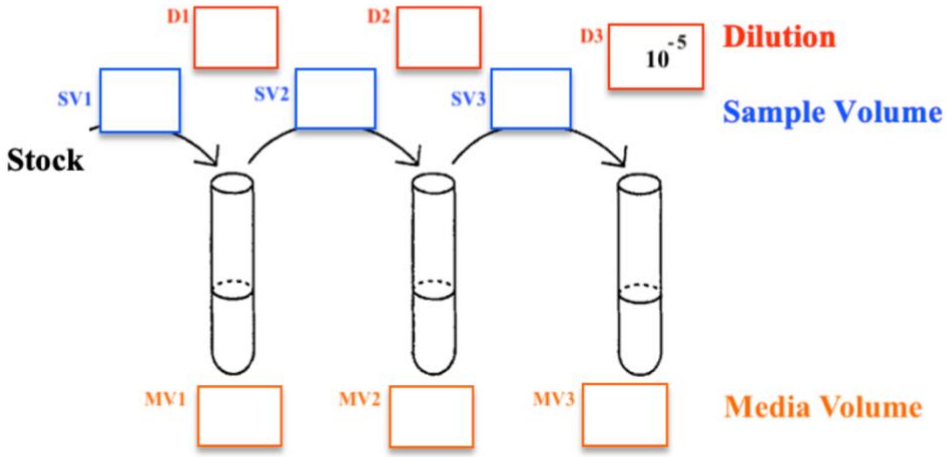
Each exam question in the online exams had multiple variants that were randomly selected and assigned to each student by the LMS, reducing the possibility of cheating.

The questions provided here evaluated the students' ability to calculate serial dilutions as well as the initial cell concentration of a sample from a hypothetical experiment. Note that in these examples the volume of diluted cells plated was the same (0.5 ml), but each experiment plated cells from a different final dilution. Also different were the numbers of colonies obtained in each experiment.

Sample question 1a

You have a bacterial culture of unknown concentration. To determine its concentration, you perform a serial dilution to 10^{-5}. From the final dilution, you spread plate 2 duplicate plates using 0.5 ml. After a 24h period, the two plates contained **45 and 35** cfu.

Design a serial dilution scheme to obtain to final dilution of 10^{-5} using 3 tubes. Fill in the blanks in the figure below.



For D numbers , please use exponential values as shown in D3.

D1:

D2:

D3: 10^{-5}

SV1:

SV2:

SV3:

MV1:

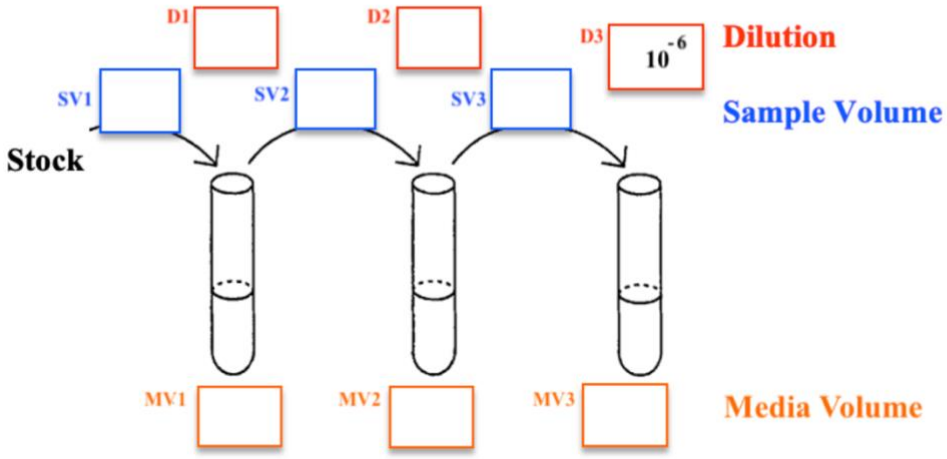
MV2:

MV3:

Sample question 1b

You have a bacterial culture of unknown concentration. To determine its concentration, you perform a serial dilution to 10^{-6}. From the final dilution, you spread plate 2 duplicate plates using 0.5 ml. After a 24h period, the two plates contained **75 and 85** cfu.

Design a serial dilution scheme to obtain to final dilution of 10^{-6} using 3 tubes. Fill in the blanks in the figure below.



For D numbers , please use exponential values as shown in D3.

D1:

D2:

D3: 10^{-6}

SV1:

SV2:

SV3:

MV1:

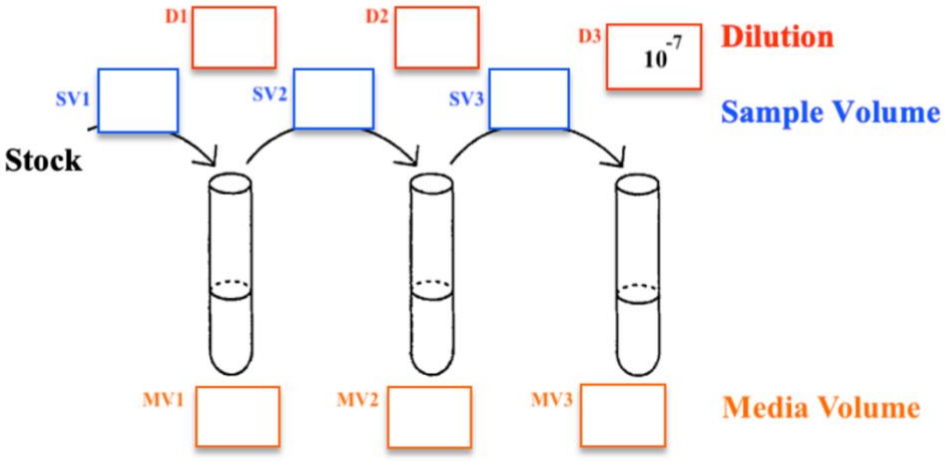
MV2:

MV3:

Sample question 1c

You have a bacterial culture of unknown concentration. To determine its concentration, you perform a serial dilution to 10^{-7}. From the final dilution, you spread plate 2 duplicate plates using 0.5 ml. After a 24h period, the two plates contained **140 and 150** cfu.

Design a serial dilution scheme to obtain to final dilution of 10^{-7} using 3 tubes. Fill in the blanks in the figure below.



For D numbers , please use exponential values as shown in D3.

D1:

D2:

D3: 10^{-7}

SV1:

SV2:

SV3:

MV1:

MV2:

MV3:

All three experimental scenarios were followed by a common math question where students calculated the initial number of cells in the stock.

Based on the colony results from the previous question, what is the concentration of the original stock?

Draw a square around your final answer and do not forget to state your units. **After the exam**, upload a picture of your calculations in the supplemental exam.

Useful formulas:

$N_t = N_0 \cdot 2^n$

$g = \frac{t}{n}$

$n = \frac{(\log N_t - \log N_0)}{0.301} = 3.3 \log\left(\frac{N_t}{N_0}\right)$