Cells, Antibiotics and Antimicrobial Peptides Lesson Plan

Grade Level: Variable - Middle School through High School

NEXT GENERATION SCIENCE STANDARDS:

- **MS-LS4-4**. Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.
- **MS-LS1-5.** Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- **HS-LS4-4.** Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

OBJECTIVES:

1. Students will hear about individual stories and research being done by undergraduate students in this field. (Part 1, Section 1)
1. Students will learn about the different cell types. (Part 1, Section 2)
2. Students will be able to describe how antibiotic resistance can develop. (Part 2, Section 1)
3. Students will learn about one possible way to combat antibiotic resistance. (Part 2, Section 2)

TIME:

45 Mins to 2 Hrs * - *This can be broken out into two or more separate days depending on which activities you'd like to do based on student's current background knowledge and time available. 2 Hrs assumes no prior knowledge.*

MATERIALS:

1. YouTube Video Clip: Diamond Moody
2. YouTube Video Clip: Akari Kumagai
3. Prokaryotic Cells, Eukaryotic Cells, Bacterial Cell Walls (Pg. 7 & 8)
4. Killer Microbe Activity
5. Tracking the Spread of Antibiotic Resistance Handout (Killer Microbe Activity)
6. Brown Paper Bags (1 per student)
7. Sheets of different colored construction paper
8. Scissors
9. YouTube Video Clip: Dr. Tristram-Nagle on Biophysics Research

VOCABULARY IN THIS LESSON:

Plasma Membrane, Cytoplasm, DNA, Ribosomes, Prokaryotic, Eukaryotic, Archaea, Peptidoglycans, Flagella, Pili Cell Nucleus, Protist, Fungi, Organelles, Bacteria, Virus, Antibiotic, Antibiotic Resistance, Natural Selection, Balance, Glove Box, Hood, Oven, X-Ray.

PROCEDURES:

1. BEGINNING – SECTION 1

Today we're going to learn about what undergraduate student researchers at Carnegie Mellon University in Dr. Stephanie-Tristram Nagle's Lab are studying. We'll see clips of their research, take a 360° digital tour the lab where they work, and hear about what motivated them to major in Applied Physics and perform research in the area of Biological Physics.

Let's start off by viewing video clips of Diamond and Akari. Pay special attention to what encouraged them in middle and high school.

Post Video Discussion Prompts:

Diamond's Video

1. How old is Diamond?
2. Who was Diamond's role model?
3. What subject was Diamond interested in initially and why?
4. Why is Diamond's advice to middle and high school students important?

Akari's Video

1. How old is Akari?
2. What experiences in middle school really stand out to Akari as being highly influential?
3. How do you relate to Akari's advice to middle and high school students?

Both Videos

1. What type of lab are they working in?
2. What are they researching?
3. Have you ever taken an antibiotic?
4. Think about a time when you or a family member had to take an antibiotic. Were they given any special instructions?
5. Why is this area of research important?

1. BEGINNING – SECTION 2

Let's do our own research study, but first we'll need some more background information.

To review, there are a few different types of cells; and for the purpose of this activity, we'll be focusing on prokaryotic and eukaryotic cells (2, 9).

All cells contain the following:

1. Plasma Membrane – outer covering
2. Cytoplasm – "jelly-like" cytosol
3. DNA – genetic material
4. Ribosomes – create proteins

Prokaryotic Cells ***(see accompanying image on pg.7)***

- Single-celled organisms
- Usually much smaller than eukaryotic cells
- Bacteria
    - Most are surrounded by a cell wall made of peptidoglycans
    - Some have flagella to move or pili to attach to other cells
- Archaea
    - Live in extreme environments such as deep sea vents or hot springs
- Have NO cell nucleus
    - DNA is found in the nucleoid

Eukaryotic Cells ***(see accompanying images on pg.7)***

- Single-celled or multicellular
- Usually larger than prokaryotic cells
- Protists (amoeba, algae, slime molds, etc.)
- Plants
- Animals
- Fungi
- Have a membrane-bound nucleus and organelles

As we're human, both viruses and bacteria can make us sick. Bacteria are alive and can cause illnesses like strep throat, salmonella, tetanus, and bacteria pneumonia to name a few. Bacteria multiply through binary fission. This essentially means that they make copies of themselves and divide. Viruses are smaller than bacteria and aren't living organisms, so they need a living host to survive and multiply. Viruses can cause illnesses such as chicken pox, common colds, and influenza.

It's important to note that NOT ALL bacteria are bad, and that we couldn't survive without the helpful bacteria that do things like protect our skin and help us digest our food. When you take an antibiotic for a bacterial infection, it doesn't differentiate between the types of bacteria (whether helpful or harmful) and can wipe out even good bacteria. So if you've ever gotten a stomach ache while taking antibiotics this could be the reason.

We'll learn a bit more about antibiotics today and what has led to antibiotic resistance.

2. MIDDLE – SECTION 1

Let's start with the Killer Microbe Activity (3) to learn about just how antibiotics were developed and how antibiotic resistance begins. *Proceed through the Killer Microbe Activity and Handout, minus the PBS videos. (Approx. 45 mins)*

2. MIDDLE – SECTION 2

Now that we have a good understanding of cell types, and how antibiotic resistance can develop let's learn how Dr. Tristram-Nagle's Lab is helping to combat this issue through the design of new antimicrobial peptides.

If we take a look at the images of bacterial cell walls ***(see accompanying image on pg.8)***, we can see that there are two basic types: Gram-positive and gram-negative. In order to break down both kinds of cell walls, and leave the host animal as unharmed as possible, research in Dr. Tristram-Nagle's lab is focused on how the use of peptides can do just that.

Take a walk with us through Dr. Tristram-Nagle's lab to see where this research is happening. In order to do this research, the following steps are performed:

360 Tour Point(s) of Interest – Balance, Sample

1. A precise amount of lipids and peptides are measured out using the balance. These are then put into a test tube or vial. After the materials are measured, they are mixed with a stock solution so that the samples can accurately be prepared. We often want to know how peptide concentrations affect the properties of the lipid membranes so it is important to carefully measure the weights of materials added to the sample. Then, the weights can be converted to moles.

360 Tour Point(s) of Interest – Glove Box

2. The glove box is used to prepare fast drying samples. We slow the drying process by allowing chloroform to evaporate into the air within the sealed box. This also keeps external debris from getting into the sample, like dust. Here samples are fixed on prepared slides using a Rock and Roll procedure.

360 Tour Point(s) of Interest – Hood

3. We use the fume hood to prepare samples that either dry slowly (the ventilation speeds the drying process) or require chemicals that release gases that should not be inhaled (the ventilation and hood cover prevents these gases from being inhaled). We also use the hood when cleaning sample wafers with acid and pouring chemicals we need.

360 Tour Point(s) of Interest – Oven

4. After the samples are made using the Rock and Roll procedure, they are dried in the oven. The oven is an evacuation oven so the air is evacuated in order to evaporate the solvent that the lipids and peptides are mixed in. The oven can also be used to dissolve lipids in stock solutions before the Rock and Roll method is performed.

360 Tour Point(s) of Interest – X-Ray Lab

5. X-ray scattering is used to collect data on our samples in both the low angle (detector is farther from the sample) and wide angle orientations (detector is closer to the sample). X-rays are scattered off of the samples to get quality data and background data is collected by scattering off the back of the samples. Then, the background data is subtracted from quality data to reduce noise from unwanted sources.

360 Tour Point(s) of Interest – Computers

6. The computers are used to analyze the data collected from the X-ray lab. To analyze the Low-Angle X-ray Scattering (LAXS) data, computer programs including Tiffview, Nfit, and a Scattering Density Profile program are used. Tiffview is used to rotate, symmetrize and adjust the X-ray data image files. Tiffview is also used to subtract the background and get a D-spacing. Nfit is used to determine the bulk modulus (B) and the bending modulus (KC). B provides information about the membrane interactions while KC indicates the stiffness of the X-rayed membrane. The Scattering Density Profile program is used to make Electron Density Profiles which layout the position of all of the components of the membrane. We can determine structural parameters such as the area per lipid, membrane thickness and peptide position within the membrane. To analyze the Wide-Angle X-ray Scattering (WAXS) data, a program in MATLAB is utilized. With the program, we determine a chain order parameter (Sxray). Sxray indicates how ordered the acyl chains in the lipid are. Finally, data is compiled using Excel and graphs of the results are created with a program called OriginPro.

For this particular study, Dr. Tristram-Nagle's lab collaborated with other researchers at various universities. Dr. Tristram-Nagle's lab focuses on results that are available from the physical lab tests that they've run and then they compare their results with computer simulations done elsewhere. See how remarkable these comparisons are as Dr. Tristram-Nagle shares slides in this clip. This study showed that similar peptides "increase stiffness and chain order at low concentrations and soften and disorder these membranes at higher concentrations. This could lead to a juxtaposition of membrane domains with different stiffness and order, which could lead to leakage between the domains along their domain boundaries." To sum it up, if a bacterial cell wall is damaged with these peptides, it could lead to bacterial cell death. In the meantime, more research will need to be done to ensure that the eukaryotic cells are not damaged with this new antimicrobial peptide.

3. ENDING

Antibiotic resistance is a growing problem as antibiotics are misused, overprescribed, and bacteria evolve through natural selection. Researchers across many universities and other research companies and organizations will need to work together to find solutions to this issue as it changes over time.

4. EVALUATION

After moving through this entire lesson, students should be able to:

- tell the differences between a prokaryotic and eukaryotic cell,
- describe the ways in which antibiotics work,
- define antibiotic resistance
- talk about what research is being done concerning antibiotic resistance

5. Differentiated Activities

- For students who had trouble learning the concepts

  There is more review available online for prokaryotic and eukaryotic cells. For more practice on cell structure and function, please visit:
  BioCoach Activity

- And/Or –

  Khan Academy – Prokaryotic and Eukaryotic Cells

  Khan Academy also offers the following for an additional overview about
  Antibiotics

- For the students who require a challenge

  Have students use the internet to search for other ways in which antibiotic resistance is being studied and how that's different from what they've just learned about.

Works Cited

1. "Antibiotics: An Overview." *Khan Academy*, Khan Academy, www.khanacademy.org/science/health-and-medicine/current-issues-in-health-and-medicine/antibiotics-and-antibiotic-resistance/a/antibiotics-an-overview.

2. "BioCoach Activity." *Pearson - The Biology Place*, www.phschool.com/science/biology_place/biocoach/cells/intro.html.

3. Cutrato, Jennifer, and Margy Kuntz. *PBS*, Public Broadcasting Service, Sept. 2008, www.pbs.org/wgbh/nova/education/activities/0303_04_nsn.html.

4. Kumagai, A., Dupuy, F.G., Arsov, Z., Elhady, Y., Moody, D., Ernst, R. K., Deslouches, B., Montelaro, R.C., Di, Y.P., Tristram-Nagle, S. 2019. *Elastic Behavior of Model Membranes with Antimicrobial Peptides Depends on Lipid Specificity and D-enantiomers*. Soft Matter 15: 1860-1868. (PDF)

5. "LGC STEM Career Explorations - Biological Physics – Akari Kumagai." *YouTube*, 5 Apr. 2019, youtu.be/4zGfMPdHEpI.

6. "LGC STEM Career Explorations - Biological Physics – Diamond Moody." *YouTube*, 5 Apr. 2019, youtu.be/HGX9h8heHTw.

7. "LGC STEM Career Explorations - Biological Physics - Dr. Stephanie Tristram-Nagle." *YouTube*, 5 Apr. 2019, youtu.be/kTAZySVHzuc.

8. Moody, Diamond, and Akari Kumagai. "Summaries of Biophysics Lab Equipment Utilized." Received by Kristin Lavery, *Summaries of Biophysics Lab Equipment Utilized*, 19 July 2018.

9. "Prokaryotic and Eukaryotic Cells." *Khan Academy*, Khan Academy, www.khanacademy.org/science/high-school-biology/hs-cells/hs-prokaryotes-and-eukaryotes/v/prokaryotic-and-eukaryotic-cells.

Prokaryotic Cell

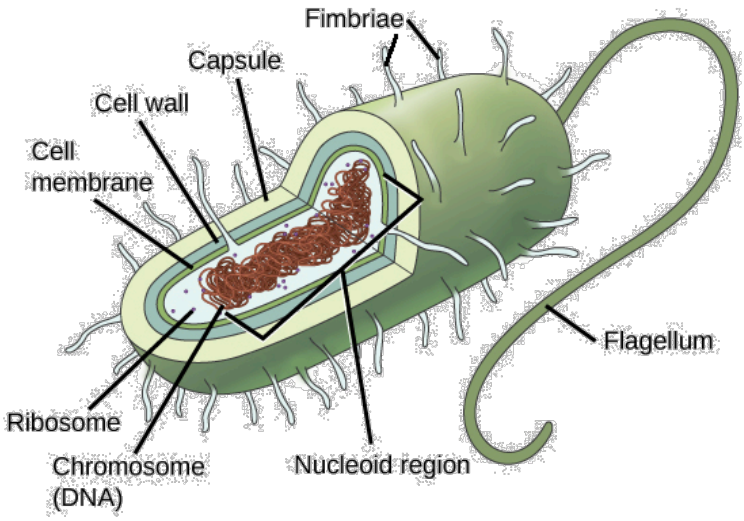
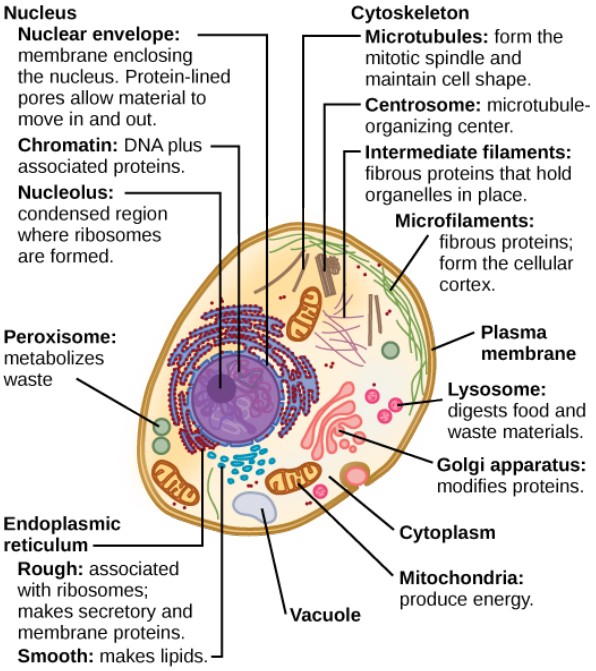


Image Credit: https://cnx.org/contents/GFy_h8cu@9.87:pOpVdIwp@11/Prokaryotic-Cells

Eukaryotic Cells

Animal Cell



Plant Cell

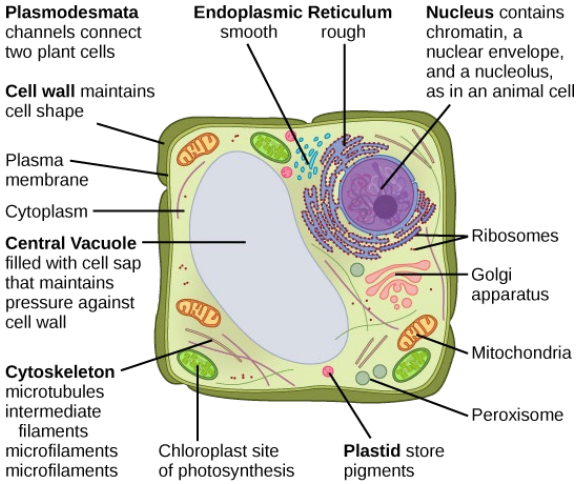


Image Credit: https://cnx.org/contents/GFy_h8cu@9.87:FPF-phhT@13/Eukaryotic-Cells

Bacterial Cell Wall

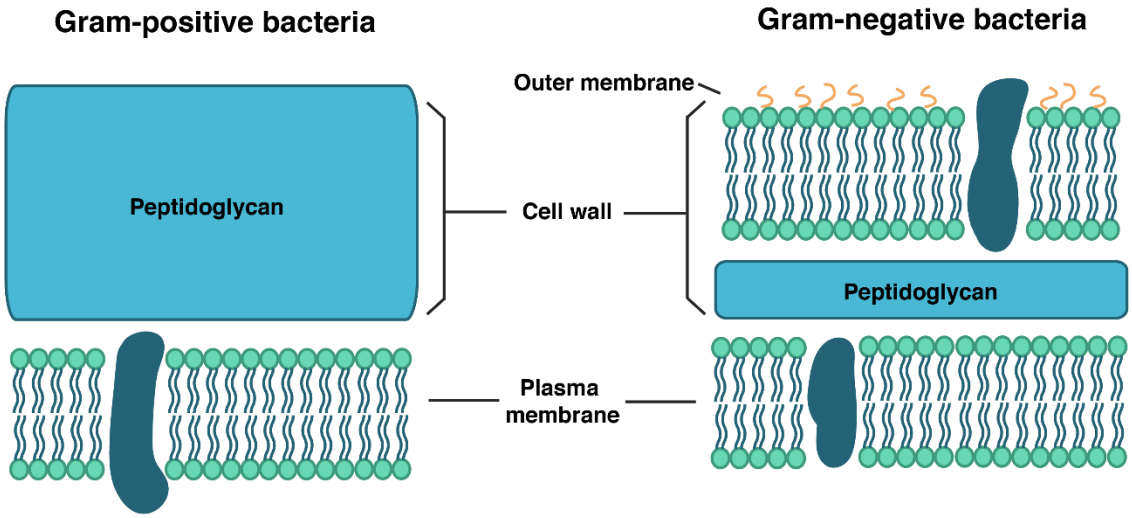


Image Credit: https://www.onlinebiologynotes.com/bacterial-cell-wall-structure-composition-types/