# Build a Bacterium Scavenger Hunt

**Resource Type:** Curriculum: Classroom

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## Abstract

In this activity, each student is provided with a worksheet and three index cards. Each card indicates a different cell part (e.g., lipopolysaccharide, capsule, DNA). Students are placed in small groups and given a written scenario regarding a bacterium with a certain goal it must carry out. They must work together to decide what cell parts are needed to form the basic structure of any cell as well as to carry out the specific functions required by their scenario. To "build" their bacterium, they must negotiate and trade index cards with other groups to acquire their desired cell parts.

## Activity

**Invitation for User Feedback.** If you have used the activity and would like to provide feedback, please send an e-mail to MicrobeLibrary@asmusa.org. Feedback can include ideas which complement the activity and new approaches for implementing the activity. Your comments will be added to the activity under a separate section labeled "Feedback." Comments may be edited.

**Learning objectives**
At the completion of this activity, students will be able to:
(i) indicate which cell parts belong to eukaryotes or prokaryotes,
(ii) identify which cell structures or parts are common to all cells and which cell structures are found only in particular bacteria,
(iii) identify specific cell structures associated with virulence and their functions, and
(iv) define microbial virulence in terms of a structure-function approach.

**Background**

This exercise was performed after covering basic eukaryotic and prokaryotic cell structure from a structure-function perspective, but before detailed discussion of molecular mechanisms of disease causation. Students should know the difference in the cellular composition of prokaryotic and eukaryotic cells and that certain structures or properties confer particular abilities on the cells, such as the ability of the acid-fast cell wall to resist uptake of certain drugs or the ability of an endospore to allow *Bacillus* species to survive in the environment for long periods of time.

**PROCEDURE**

**Materials.**

Student handouts, index cards naming cell parts, plus one scenario given to each group (in instructor handout version).

**Student Version.**

See handout.

**Instructor Version.**

See handout.

This activity takes about 20 to 30 minutes, perhaps 10 minutes more if the instructor goes over group solutions with the class immediately after they solve their scenarios. Alternately, students can hand in their worksheet for grading.

**Safety Issues.**

None.

**Suggestions for Assessment.**

This activity is designed to be conducted as an in-class activity on the day these concepts are discussed in class (or the following day). Conceivably, students could work on this activity at home, working from a list of cell parts. They can hand in the student worksheet for points (see Evaluation Criteria).

Evaluating the worksheets gives a good idea of student misconceptions, e.g., can they distinguish prokaryotic parts from eukaryotic (do they insist prokaryotes need a nucleus?). By their inclusion on the worksheet of alternative strategies to achieve their scenario, their level of sophistication in understanding the versatility of these parts and the various names for them (outer membrane or lipopolysaccharide), as well as the overall variation in overall microbe structure, can be gauged.

**Field Testing.**

This activity was used in a 200-level allied health medical microbiology lecture class of up to 40 students with groups of four students. The activity is flexible because the number of groups can be increased by adding additional scenarios or duplicating scenarios among groups, or decreased by decreasing group size.

In one semester, 18 out of 24 students elected to fill out an anonymous survey, while in another semester, 36 out of 41 students elected to fill out the survey. These surveys indicated a high level of effectiveness in achieving the learning objectives as rated on a Likert scale of 1 (strongly disagree) to 5 (strongly agree). Statements such as "I thought this learning method was stimulating/interesting," "This activity helped me learn more (or apply) my knowledge of the parts of a cell and virulence," "This activity helped me understand prokaryotic versus eukaryotic cell structure," and "This activity helped me distinguish between fundamental versus "optional" cell structures" all scored between 3.9 and 4.3. In addition, the activity instructions were clear (4.0), and students displayed a mild preference (3.9) for learning this way versus lecture delivery, but did not feel that it increased their interest in microbiology much (3.4).

One benefit of this activity is that it gets students talking to each other, verbally reviewing information and correcting each other, and thus thinking critically about the material. For example, students were arguing for one cellular structure versus another in a scenario where both alternatives were viable to achieve a given purpose (e.g., adherence involving a capsule or flagella).

Students worked animatedly as they moved around the room and seemed to enjoy the bartering process of acquiring parts from each other. Some joked about having to trade parts of perceived "high" value for those of "low" value or being pleased at getting "something for nothing" (if another student just gave them a cell part and they didn't need to give up something in return). However, the goal is not to force a 1-for-1 trade of cell parts, although those giving away parts they later found they needed were chagrined. If needed, one can quickly supply additional parts or allow them to "conjugate" to get the desired parts.

Many students commented something like: "This activity helped me remember things better because you had to apply your knowledge." They also liked to "apply the lecture material to a real scenario" and said that, "This allows you to understand, not just memorize. This is a higher level of learning." Students also appreciated the change in format from lecture and the chance to interact with fellow students: "You might have a student in the group who has another view on the topic and can explain it differently." This was seen when the inclusion of different but related terms, such as glycocalyx, slime layer, and capsule required students to question each other about the precise meanings of those terms and discuss the content. Finally, the hands-on work "helped me visualize what cell parts went with each type of cell."

**SUPPLEMENTARY MATERIALS**

**Supplementary Modifications.**

Some students proposed modifications to the exercise to develop it further and make it more difficult. They proposed creating pictures of the various cell parts (which could be created ahead of time by the students themselves or could be provided by the teacher as actual micrographs) that could then be traded or used to create a physical model that could be assembled and hung on the wall (pin the flagellum on the microbe?). This would reinforce the visual recognition of cell parts seen in lecture presentations. Others suggested adding more "wrong" cell parts (e.g., eukaryotic structures if trying to construct prokaryotic cells) or building scenarios for protozoa, viruses, and fungi to be used when discussing those organisms in class. Students themselves can also try to design scenarios for other groups to solve.

The activity can be further expanded and modified to focus on the difference between prokaryotic and eukaryotic cells (e.g., include many more organelles for them to distinguish between), fungi (e.g., different morphological forms such as yeasts or moulds), viruses, or even nonpathogens (enzymes and metabolic pathways needed to carry out a biochemical scenario such as bioremediation). Modifications could also include having students model horizontal gene transfer through conjugation or transduction of antibiotic resistance or toxin genes, etc., whose phenotype could be identified as contributing to virulence. See Instructor Version handout for suggestions on creating scenarios.

Finally, one could expand on this topic and assign students to read an article on the developing field of synthetic biology (the proposed "creation" of a newly "designed" organism from parts). This approach to understanding requirements for cellular life is the focus of serious investigation.

**Appendices.**

Student Version

Instructor Version

Evaluation Criteria

Student Assessment Form

Assessment/Results Summary

# "Build–a-Bacterium: a Scavenger Hunt"

**Goal**: to work in teams to learn the parts that make up a bacterium, what parts are common to all cells versus the ones that are only found in particular bacteria, and what parts might contribute to the disease process.

1) Review what the necessary parts of **any** cell are and what additional parts a bacterium might have.

a) Common cell parts list (may not use all blanks):

______________________________ ____________________________ _____________________________

______________________________ ____________________________ _____________________________

b) "Additional" parts (may not use all blanks):

______________________________ ____________________________ _____________________________

______________________________ ____________________________ _____________________________

______________________________ ____________________________ _____________________________

2) Now for the scavenging! You will be presented with a scenario, below, which describes what traits or activities are needed to carry out a certain infection. Keep in mind that you need to form a complete working bacterium, so pay attention to the required as well as the additional parts.

According to your scenario, your group's mission is to:
(i) decide what parts you'll need to effectively carry out the invasion, intoxication, etc. of the host you will infect, and,
(ii) "make" a bacterium by collecting all the parts. To do this, talk to the other groups and trade parts with them to get what you need to make your bacterium. Then raise your hands and yell "bacterium bingo" or some suitable cute phrase.

List the parts (both common and additional) you need:

| Cell part needed | Why do you need this part? What is its function? |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

Are there any alternative ways this scenario could be accomplished?

Is there any particular microbe you can think of that fulfills the requirements of your scenario?

# "Build-a-Bacterium" Scavenger Hunt
# Instructor Version

## A. Classroom procedure

1) Prepare scenarios and cell parts.

a) Print out one scenario per student group on a slip of paper (see scenarios below).

b) Write names of cell parts (see scenarios and word list below) on index cards.

Sufficient duplicate cell parts should be prepared so each group can acquire DNA, a cell membrane, cytoplasm, and ribosomes. For example, if there are 30 students in your class, with 10 groups of three students, then you must prepare 10 cards that say "DNA," 10 cards that say "cytoplasm," etc. Prepare multiple copies of other cells parts, as multiple groups may wish to have "pilus" or "lipopolysaccharide."

You may wish to sort the cell parts cards into piles of two to three cards with the cell parts strategically distributed so each group will likely need to barter with other groups. For example, to a group of two students, give one person "DNA," "lipopolysaccharide", and "nucleus," and the other person, "cell membrane," "peptidoglycan," and "flagella." This ensures that this group will need to trade with others to acquire their ribosomes and cytoplasm, as well as other parts.

2) Hand out one worksheet to each student and instruct students to work in groups to solve and answer part 1 on the worksheet.

3) After 5 to 10 minutes of working on part 1, hand out scenarios and approximately two to three index cards to each student and instruct them to barter and physically move around the room to other groups to talk and trade or give away cell parts. Tell them that not all index cards must be used to complete their scenario.

4) Students fill out part 2 of the worksheet individually after working with their group.

5) You may choose to have all students hand in the worksheet or discuss their results and rationale for their choices as a class.

## B. Suggestions for writing additional scenarios

Although these scenarios are based on the activities of microbes involved in host-pathogen relationships, you may wish to write additional scenarios about specific bacteria that are nonpathogens but important in the environment or industry, or even about eukaryotic organisms or viruses, depending on the level and focus of the class.

You can either construct a scenario focused on specific parts (or attributes or enzymes) you wish them to focus on, or you can take an actual microbe that you are studying and determine which parts are needed to construct that microbe. Then write a description of activities that the microbe would engage in, based on the function that requires a particular cell part. For example, allude to the environment the bacterium would likely find itself in where it would express that cell part. Alternatively, describe an activity that the bacterium would do, for which it would need a certain cell part. These additional scenarios might require making additional "cell parts" index cards.

## C. Evaluation

Required cell parts for each scenario include: DNA, cytoplasm, cell membrane, ribosomes. Suggested additional cell parts are indicated after the scenarios. (Boldfaced words, which provide students with hints, may be left boldfaced at the instructor's discretion when the scenarios are given to students.) See instructor rubric for assessing worksheets.

SCENARIOS

A. Although you intend to make your living in a human for many years to come, you're kind of an isolationist.  Slow and steady wins the race, you say, although some say you're a bit stiff, like a **statue in a wax museum**.

B. You finally feel ready to **settle down in one spot** for good this time.  But first you've got to find your way to the right spot.

C. You're a bit of a swinger—you're looking to **swap genes** with someone, preferably someone who can resist the effects of that newest antibiotic on the market.

D. You're kind of an **outdoorsy** type of microbe—but you would need a moisturizer, it's so **dry** out there.  Why don't you just hang out outdoors? You're in **no hurry** to annoy those big humans anyway.

E. You're **sneaky** and would like to **avoid** the deadly grip of white blood cell phagocytes.  Plus, you've got a **sweet** tooth.

F. It made you happy to live in your human host, once you **found your way** to a good spot.  Of course, they're not happy having you in them, but if they kill you, they're in for a nasty surprise!  Revenge of the **killer** microbes!

G. You have found yourself between a rock and a hard place—good thing you know how to wriggle out of this sticky situation.  You'll **twist and turn**, but at least you won't twist yourself in knots.

H. You're unique—you don't like to conform to any one shape, like other bacteria.  If they don't like it, they can get walking (**pneumonia, that is**).

## Scenario answers

A. Suggested answers: acid fast microbe; *Mycobacterium tuberculosis* or *Mycobacterium leprae*
Suggested additional cell parts: peptidoglycan, mycolic acids

B. Suggested answer: adherence
Suggested additional cell parts: peptidoglycan, flagellum or axial filament; capsule, fimbriae, or slime layer

C. Suggested answer: any cell capable of conjugation, e.g., *Escherichia coli*
Suggested additional cell parts: peptidoglycan, (sex) pilus

D. Suggested answer: spore-forming bacterium such as *Bacillus* or *Clostridium*
Suggested additional cell parts: peptidoglycan, endospore

E. Suggested answer: capsulated microbe; *Streptococcus pneumoniae*
Suggested additional cell parts: peptidoglycan, capsule

F. Suggested answer: motile, gram-negative bacterium
Suggested optional cell parts: peptidoglycan, flagellum or axial filament, outer membrane or endotoxin

G. Suggested answer: motile spirochete bacterium
Suggested optional cell parts: peptidoglycan, endoflagella or axial filament or periplasmic flagella

H. Suggested answer: pleomorphic, *Mycoplasma pneumoniae*
Suggested optional cell parts: NOT peptidoglycan

## Cell parts word list

These are examples of cell parts, which include various eukaryotic parts that may be useful as “red herrings,” or if you wish to include, for example, protozoan or fungal scenarios.

DNA (required for any cell)
Cytoplasm (required for any cell)
Cell membrane (required for any cell)
Ribosomes (required for any cell)
Peptidoglycan
Endospore
Nucleus
lipopolysaccharide
Mycolic acids
Glycocalyx
Golgi apparatus
Plasmid
Flagella
Axial filament
Slime layer
Chloroplast
Capsule
Cilia
Mitochondrion
Outer membrane
Endoflagella
Sex pilus
Fimbriae
Outer membrane

Build-a-Bacterium Student Worksheet Evaluation Criteria

| Criterion | 1<br>Perfect | 2<br>Some mistakes | 3<br>Many mistakes or blank | Comments |
|---|---|---|---|---|
| 1a) Identifies common parts of any cell | | | | |
| Includes **all** common parts | | | | |
| Does **not** include any parts as common that are specialized | | | | |
| 1b) Only chooses prokaryotic parts (e.g., does not choose mitochondria or nucleus) | | | | |
| 1b) Only chooses "additional" parts | | | | |
| 1b) Chooses **all** possible "additional" parts | | | | |
| Includes a list of parts and abilities that will allow their cell to complete the given scenario | | | | |
| Describes what role each cell part plays | | | | |
| Describes how the specialized cell parts contribute to virulence | | | | |
| Shows understanding of alternative strategies bacteria may use to carry out scenario, e.g., by proposing alternate strategies | | | | |
| States a particular microbe name that could be associated with this scenario, e.g., a *Bacillus* carrying out persistence in the environment. (Not required but gives evidence of additional thinking) | | | | |

“Build-a-Bacterium” activity survey

I ask you these questions to help me improve the class and determine whether the activities that we do are helpful for your learning.  You are not required to give any answers, and your specific answers have NOTHING to do with your grade in this class.  I need and appreciate your HONEST feedback. Don’t put your name on this (type on it if you wish).  Thank you!!

Please respond to the statements about the “Build-a-Bacterium” activity using the scale shown below.

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| strongly disagree | moderately disagree | neither agree nor agree | moderately agree | strongly agree |

1. Doing this enhanced my learning about the subject. ________
2. The activity was clear (in what I was supposed to do). ________
3. It was of an appropriate intellectual level (hard/easy). ________
4. I liked learning in this way better than lecture. ________
5. It increased my interest in microbiology. ________
6. I thought this learning method was stimulating and/or interesting. ________
7. This activity helped me **learn more** about the parts of a cell and a cell’s virulence. ________
8. This activity helped me to **apply and practice** my knowledge of the parts of a cell and virulence. ________
9. This activity helped me understand prokaryotic versus eukaryotic cell structure. ________
10. This activity helped me distinguish between fundamental versus “optional” cell structures. ________

I welcome your comments on how to improve this activity.  What would make it better or a more accurate review of what we learned?

If you enjoyed doing this type of activity, or felt it was helpful, **why** did you enjoy it or learn from it?

What, in your opinion, are the pros and cons of doing this particular activity, versus just listening to lecture on this topic?

Assessment Results and Summary

TABLE 1. Student assessment of the Build-a-Bacterium activity

| Statement students rated | Average semester 1[a] | Average semester 2[b] | Mode[c], all semesters |
|---|---|---|---|
| 1) Doing this enhanced my learning about the subject | 4.2 | 4.0 | 4 |
| 2) The activity was clear (in what I was supposed to do) | 4.5 | 3.7 | 4 |
| 3) It was of an appropriate intellectual level (hard/easy) | 4.1 | 4.2 | 4 |
| 4) I liked learning in this way better than lecture | 3.9 | 4.0 | 4 |
| 5) It increased my interest in microbiology | 3.1 | 3.6 | 3 |
| 6) I thought this learning method was stimulating and/or interesting | 4.4 | 4.1 | 4 |
| 7) This activity helped me learn more about the parts of a cell and a cell's virulence | 4.2 | 4.1 | 4 |
| 8) This activity helped me to apply and practice my knowledge of the parts of a cell and virulence | 4.4 | 4.2 | 4 |
| 9) This activity helped me understand prokaryotic versus eukaryotic cell structure | 4.3 | 3.7 | 4 |
| 10) This activity helped me distinguish between fundamental versus "optional" cell structures | 4.3 | 4.2 | 5 |

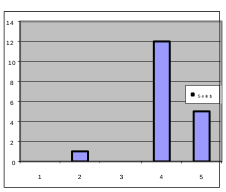
[a] 18 of 24 students represented.

[b] 36 of 41 students represented.

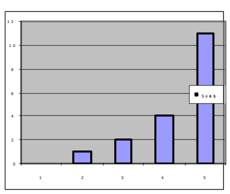
[c] The medians were identical to the mode, except on question 10 where the median was 4.

Distribution of answers to these questions from semester 1.

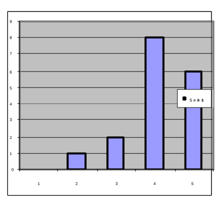
Question 1.



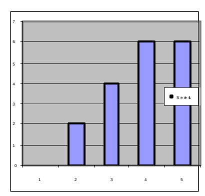
Question 2.



Question 3.



Question 4.



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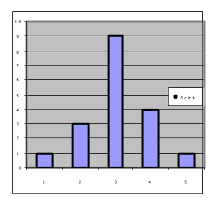
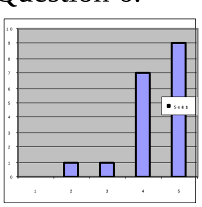
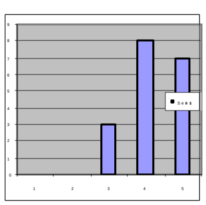


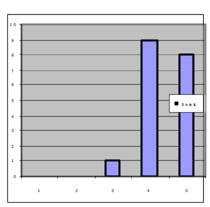
Question 6.



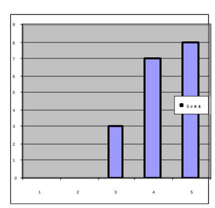
Question 7.



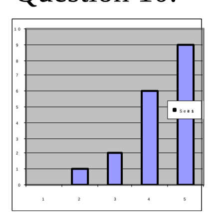
Question 8.



Question 9.



Question 10.



**Evidence of student learning**

On a test in semester 1, students were asked these questions (test average: 72.7%, n = 25).

1a) Circle in this list all possible cell parts that could be found on/in a prokaryotic cell:

Cell wall
Cilia
Flagella
Nucleus
Pilus
Capsule
Mitochondria
Endospore

> **The student score average was 78%. The class average was 6.25 items correctly circled. I explain that they get points for circling things that should be circled, as well as points for NOT circling things that should not be circled. This is like 8 true-false questions.**

1b) For each circled cell part, describe what this part of the cell does.

> **The student score average was 77.5%.**

2) Name the kind of bacterium that possesses mycolic acids in their cell wall (name genus and species or give a general description).

> **The student score average was 68% answered correctly; (6 said "acid fast," 11 said *Mycobacterium tuberculosis* or *Mycobacterium leprae*, and some said both).**

3) Which of the following cell structures can play a role in in-"toxic"-ating the human host?
a) gram-positive cell wall
b) flagella
c) gram-negative cell wall
d) cell membrane
e) endospore

> **Student scores: 68% answered correctly (20% expected due to chance).**