Classification

In an old game called Animal, Vegetable, or Mineral, one person thought of an object, then told the other players whether the object was an animal, a vegetable (that is, a plant), or a mineral (just about everything else). To identify the object, the players were allowed to ask 20 questions which could be answered yes or no. If the object were an animal, the next question was usually an attempt at a kind of classification—"Does it have four legs?" or "Does it have wings?" Often, the players could identify the object before using up their 20 questions. Interestingly, players never seemed to argue over the beginning classification of the object; there was always general agreement over whether it was in fact animal, vegetable, or mineral.

How would we play the game today? Let's leave out mineral and consider only biological agents. First of all, animal or vegetable would not work for us because we know of agents that don't fit into either group. I will propose that instead the players should be told first whether the object is cellular or noncellular.

Below is a hypothetical game. One person, whom we'll call Player #1, is thinking of an object.

Player #1: The agent I am thinking about is cellular.

Other player: Is it eukaryotic?

Player #1: No.

Other player: Then it must be prokaryotic. Does it belong to the domain *Bacteria*?

Player #1: Yes.

Other player: Ok, it is not one of the *Archaea*. Is it Gram-negative?

Player #1: No.

Other player: Is it Gram-positive?

Player #1: Yes.

Other player: Is it a coccus?

Player #1: No.

Other player: Is it rod-shaped?

Player #1: Yes.

Other player: Does it form endospores?

Player #1: Yes.
Player #1: Yes.

Other player: Does it cause disease?

Player #1: Yes.

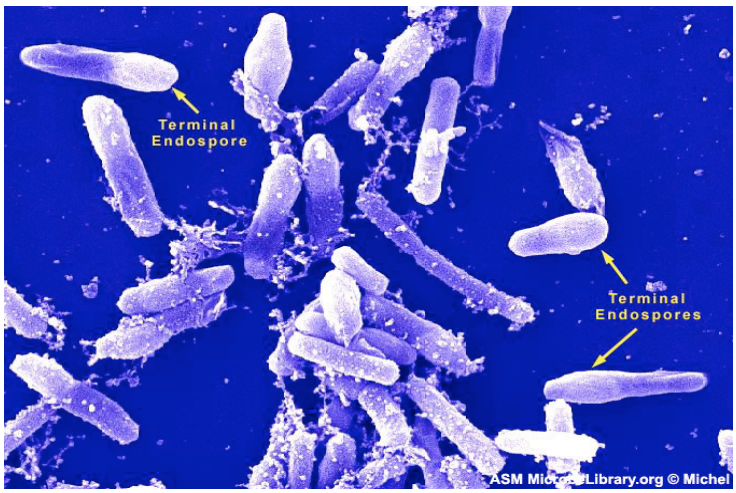
Other player: Is this an organism that was in the news soon after September 11, 2001, and was found in some letters in the Senate Office Building?

Player #1: Yes.

Other player: It must be *Bacillus anthracis*, the bacterium that causes anthrax.

Player #1: Yes.

Other player: Is it a member of the genus *Bacillus*?



Scanning electron micrograph of a *Bacillus* isolated from a compost pile. Frederick Michel, author. Licensed for use, ASM MicrobeLibrary (linked to http://www.microbelibrary.org)

Eleven questions—not bad. The players made several lucky guesses towards the end, but this is a bacterium that had a lot of publicity and would be a likely organism for a group that is familiar with some basic microbiology. You can imagine that a group of experts could make this really hard.

Let's go back and look at the clue Player #1 gave to start the game and some of the questions that were asked.

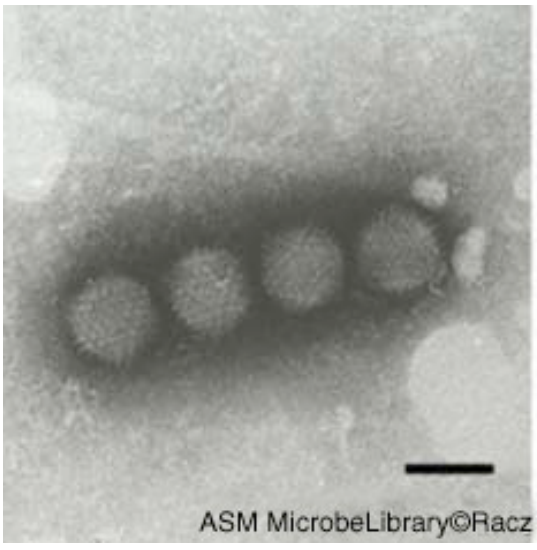
Player #1 told the players that the agent he was thinking of is cellular.

If the agent were noncellular, it would probably be a virus, but not necessarily. There are a couple of other noncellular agents: viroids and prions. Viroids and prions are very curious biological agents.

A viroid is a small molecule of single-stranded circular RNA and lacks protein, but viroids have the ability to infect cells of some plants and reproduce there. Once inside a plant cell, a viroid can be replicated by the plant cell enzymes, and the new viroid particles can spread to infect other cells. Some viroids cause diseases in important crops such as potatoes, tomatoes, and coconuts. Viroids are the smallest pathogens known.

Prions, on the other hand, are protein and lack all forms of nucleic acid. The most famous (or notorious) prion is one that causes Mad Cow Disease [bovine spongiform encephalopathy (BSE)] and also a related disease in humans—a type of Creutzfeld-Jakob disease. Prions aren't well understood.

How are viroids and prions different from viruses? Even the smallest virus has both a protein coat *and* a nucleic acid genome, which carries its genetic information. The nucleic acid genome can be either DNA or RNA, single-stranded or double-stranded. Cellular organisms, in contrast, *always* carry their genetic information in double-stranded DNA. Virus particles often have a symmetrical shape (see the adenovirus particles below).



Adenovirus particles
Note the icosahedral symmetry

Electron micrograph of adenovirus particles
Maria-Lucia Racz, Jonas Jose Kisielius, Marli Ueda, authors. Licensed for use, ASM MicrobeLibrary (linked to http://www.microbelibrary.org)

Viruses, viroids, and prions are all very, very small. Viruses are about 0.3 micrometers in diameter or less, mostly less, and most can't be seen with a light microscope. Viroids and prions are even smaller than viruses. All of these agents have one other important thing in common, too. They are all obligate intracellular parasites. That means that they don't replicate until they are inside a cell, which is kind of an unwilling host. They use the cell's resources to make copies of themselves. Most of the time, the cell is damaged or destroyed by the activities of the invader.

But Player #1 said the agent was cellular. The first question was "Is it eukaryotic?"

For a long time, everyone agreed that the way to classify biological agents was to group them into two kingdoms (1) plant and (2) animal. Then things got a bit more interesting, or at least more complicated. As more was learned about microorganisms, it became clear that from a structural standpoint, there are in fact two basic kinds of cells.

The more familiar kind of cell always has a nucleus surrounded by a membrane. These cells are called eukaryotic, *eu-* meaning "true" and *–karyon* referring to the nucleus. So eukaryotic cells are "true nucleus" cells. The nucleus of eukaryotic cells contains multiple chromosomes, which are linear.

A bacterial cell, on the other hand, typically has one chromosome, which is circular and does not have a membrane around it. These cells are called prokaryotic, meaning "primitive nucleus" or, perhaps better, "before nucleus" cells. In addition, they are usually smaller than eukaryotic cells, often about one micrometer in diameter plus or minus a little. Eukaryotic cells are usually about eight micrometers or larger, mostly larger. Another difference is that eukaryotic cells have mitochondria, an endoplasmic reticulum, and Golgi bodies; prokaryotic cells don't. In the figure below (a) is a diagram of a prokaryotic cell and (b) is a diagram of a eukaryotic cell.

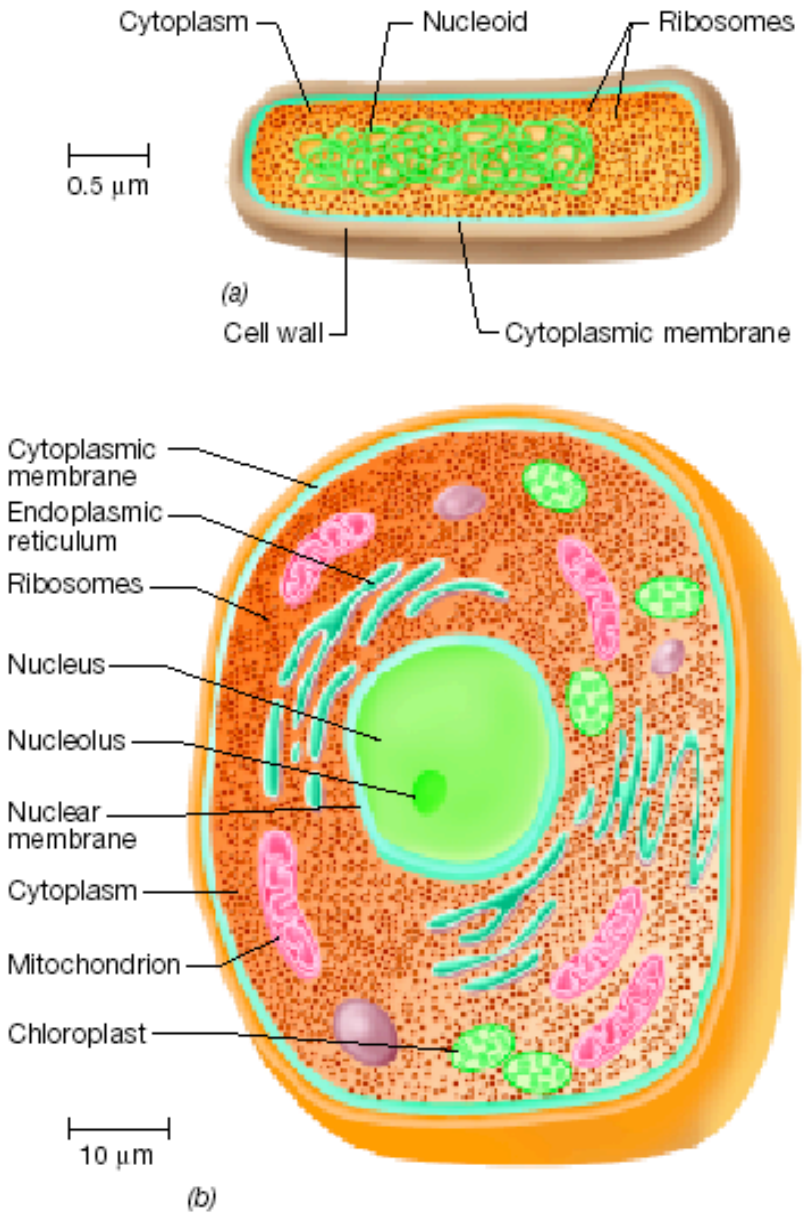
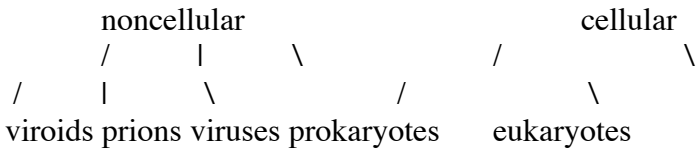


Figure from *Brock Biology of Microorganisms*, 10th ed., by Michael Madigan, John Martinko, and Jack Parker. The publisher is Prentice Hall, Upper Saddle River, NJ, 2003. Used with permission.

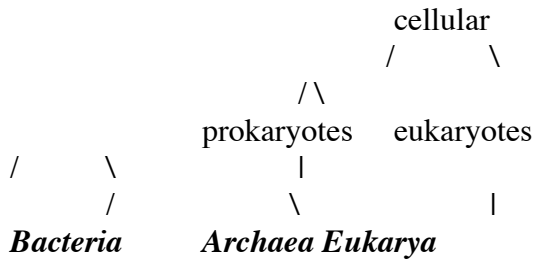
Eukaryotic cells also have bigger, more complicated ribosomes. Another difference is that prokaryotic cells are single-celled organisms, that is, each cell is an independent organism. Most eukaryotic cells are part of a multicellular organism (like us), although some are single-celled organisms. The most familiar example of a eukaryote that is a single-celled organism is yeast.

To review so far, look at the following chart.



In the 1970s, a surprising finding was made: there are really two different groups of prokaryotes. One group includes organisms like *Bacillus anthracis* and species of the genera *Streptococcus* and *Staphylococcus*, and this group is called the *Bacteria* (notice the capital B and italics). The other group is composed of very unusual organisms. They are single celled, prokaryotic, and have many of the same characteristics as *Bacteria*. In some ways, however, they resemble eukaryotic cells. This kind of cell seems to be very ancient, and this group is called the *Archaea.*

Biologists now generally agree to classify cellular organisms into three groups called Domains as follows:



For an explanation of the remaining questions in the game, see the module entitled Prokaryotes.

Places to Go and Things to See
The following websites contain information and images that can be used to explore further.

1. The micrographs of *Bacillus* and adenovirus particles were taken from the American Society of Microbiology website.

To access other information and images on this site, go to .□□
http://www.microbelibrary.org/Visual/page1.htm

From this page, you can go two different ways.

1. Near the top of the page, click on **Search Visual Resources**.
   This will take you to a page that explains the rules for using materials from MicrobeLibrary. Permission is granted for use of the images for educational purposes, but users are asked to inform and credit the authors and the American Society for Microbiology (ASM). To see the images on this site, click **Accept** and you will be

allowed to enter the site and taken to the ASM MicrobeLibrary Search Screen. To see the entire list of images available, skip all the drop-down menus and click on **Submit**.

2. At the bottom of the page, click on **Additional Microbial Resources**. This will take you to a page with a list of links to other sites with a wealth of other information.

   - A website with wonderful images and other information about viruses is found at . . . http://www.uct.ac.za/depts/mmi/stannard/linda.html

   - A website which discusses Domains is . . . http://helios.bto.ed.ac.uk/bto/microbes/microbes.htm Click on **Tree of Life**.

Questions

Choose the one correct answer to each of the following questions.

1. Which of the following are properly described as cellular?
   a. bacteria
   b. viruses
   c. viroids
   d. prions
   e. both a and b

2. A prokaryotic cell contains . . .
   a. a membrane-bounded nucleus.
   b. endoplasmic reticulum.
   c. Golgi bodies.
   d. all of the above
   e. none of the above

3. Chromosomes in the nucleus of a eukaryotic cell are properly described as . . .
   a. linear, one chromosome in each nucleus.
   b. circular, one chromosome in each nucleus.
   c. linear, multiple chromosomes in each nucleus.
   d. circular, multiple chromosomes in each nucleus.
   e. a, b, c, or d

4. Chromosomes in cellular organisms are composed of . . .
   a. single-stranded DNA.
   b. double-stranded DNA.
   c. single-stranded RNA.
   d. double-stranded RNA.
   e. protein.

5. An agent composed of RNA only is a . . .
   a. prion.
   b. viroid.
   c. virus.
   d. bacterium.
   e. eukaryote.

6. Which of the following are prokaryotic?
   a. Archaea
   b. Bacteria
   c. Eukarya
   d. a and b
   e. b and c

7. An agent described as single-celled could be . . .
   a. a eukaryote.
   b. a prokaryote.
   c. a virus.
   d. either a or b
   e. either a, b, or c

8. A noncellular agent consisting of a nucleic acid genome and a protein coat is . . .
   a. a virus.
   b. a viroid.
   c. a prion.
   d. a bacterium.
   e. either a or b

9. Which of the following is the smallest?
   a. a eukaryotic cell
   b. a prokaryotic cell
   c. a viroid
   d. a virus

10. Viroids cause . . .
   a. Mad Cow Disease (bovine spongiform encephalopathy).
   b. a variety of plant diseases.
   c. Creutzfeld-Jakob disease.
   d. all of the above
   e. none of the above; viroids do not cause harm to their hosts.

Answers

1. a
2. e
3. c

4. b
5. b
6. d
7. d
8. a
9. c
10. b