BIOZONE

Student Workbook

Senior Biology 1

FREE Sample

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Bacterial Cells

Bacterial (prokaryotic) cells are much smaller and simpler than the cells of eukaryotes. They lack many eukaryotic features (e.g. a distinct nucleus and membrane-bound cellular organelles). The bacterial cell wall is an important feature. It is a complex, multi-layered structure and often has a role in virulence. These pages illustrate some features of bacterial structure and diversity.

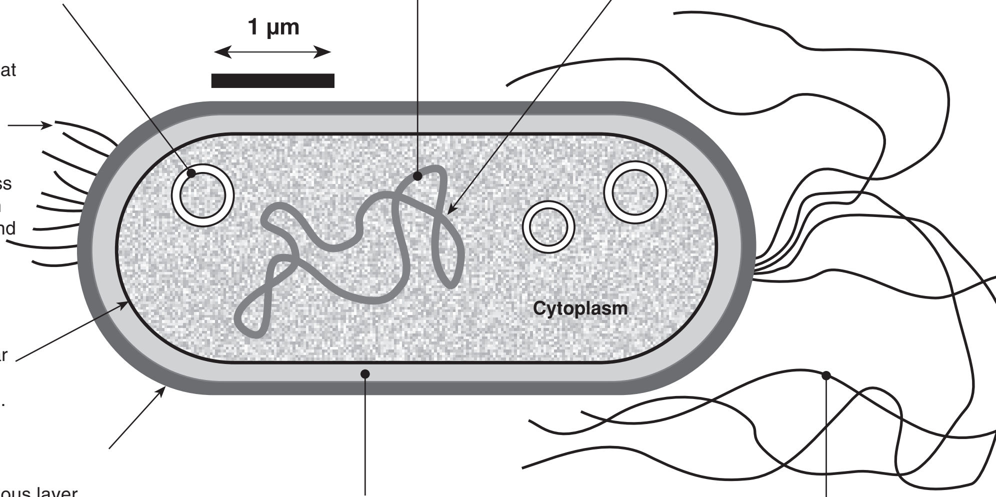
Structure of a Generalized Bacterial Cell

Plasmids: Small, circular DNA molecules (accessory chromosomes) which can reproduce independently of the main chromosome. They can move between cells, and even between species, by **conjugation**. This property accounts for the transmission of antibiotic resistance between bacteria. Plasmids are also used as vectors in recombinant DNA technology.

Single, circular main chromosome: Makes them haploid for most genes. It is possible for some genes to be found on both the plasmid and chromosome and there may be several copies of a gene on a group of plasmids.

The cell lacks a nuclear membrane, so there is no distinct nucleus and the chromosome is in direct contact with the cytoplasm. It is possible for free ribosomes to attach to mRNA while the mRNA is still in the process of being transcribed from the DNA.

Fimbriae: Hairlike structures that are shorter, straighter, and thinner than flagella. They are used for attachment, not movement. Pili are similar to fimbriae, but are longer and less numerous. They are involved in bacterial conjugation (below) and as phage receptors (opposite).



Cell surface membrane: Similar in composition to eukaryotic membranes, although less rigid.

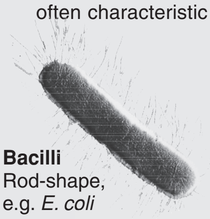
Glycocalyx. A viscous, gelatinous layer outside the cell wall. It is composed of polysaccharide and/or polypeptide. If it is firmly attached to the wall, it is called a **capsule**. If loosely attached, it is called a **slime layer**. Capsules may contribute to virulence in pathogenic species, e.g. by protecting the bacteria from the host's immune attack. In some species, the glycocalyx allows attachment to substrates.

Cell wall. A complex, semi-rigid structure that gives the cell shape, prevents rupture, and serves as an anchorage point for flagella. The cell wall is composed of a macromolecule called **peptidoglycan**; repeating disaccharides attached by polypeptides to form a lattice. The wall also contains varying amounts of lipopolysaccharides and lipoproteins. The amount of peptidoglycan present in the wall forms the basis of the diagnostic **gram stain**. In many species, the cell wall contributes to their virulence (disease-causing ability).

Flagellum (pl. flagella). Some bacteria have long, filamentous appendages, called flagella, that are used for locomotion. There may be a single polar flagellum (monotrichous), one or more flagella at each end of the cell, or the flagella may be distributed over the entire cell (peritrichous).

Bacterial cell shapes

Most bacterial cells range between 0.20-2.0 µm in diameter and 2-10 µm length. Although they are a very diverse group, much of this diversity is in their metabolism. In terms of gross morphology, there are only a few basic shapes found (illustrated below). The way in which members of each group aggregate after division is often characteristic and is helpful in identifying certain species.



Bacilli
Rod-shape,
e.g. *E. coli*

Bacilli: Rod-shaped bacteria that divide only across their short axis. Most occur as single rods, although pairs and chains are also found. The term bacillus can refer to shape. It may also denote a genus, e.g. *Bacillus anthracis.*

Cocci
Ball-shaped
e.g. *Staphylococcus*

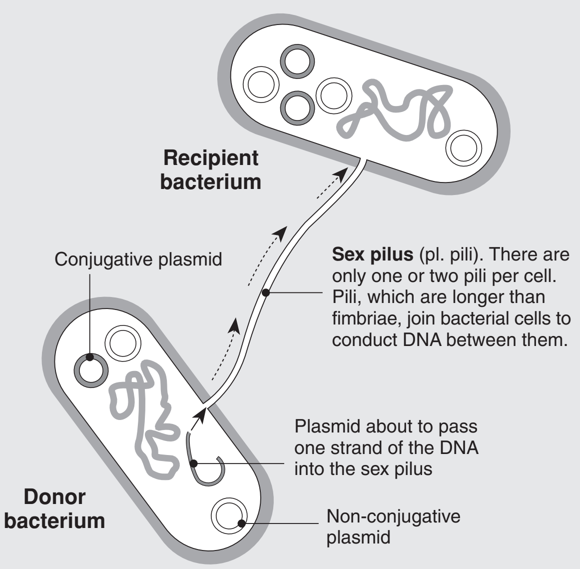
Cocci: usually round, but sometimes oval or elongated. When they divide, the cells stay attached to each other and remain in aggregates e.g. pairs (diplococci) or clusters (staphylococci), that are usually a feature of the genus.

Spirilla
Spiral-shaped
e.g. *Leptospira*

Spirilla and vibrio: Bacteria with one or more twists. Spirilla bacteria have a helical (corkscrew) shape which may be rigid or flexible (as in spirochetes). Bacteria that look like curved rods (comma shaped) are called vibrios.

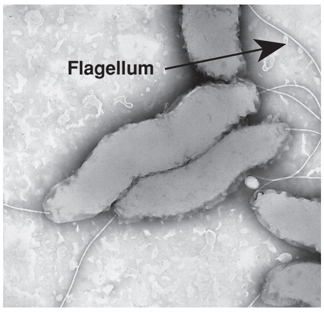
Bacterial conjugation

The two bacteria illustrated below are involved in 'pseudo sex'. This involves a one-way exchange of genetic information from a donor cell to a recipient cell. The plasmid, which must be of the 'conjugative' type, passes through a tube called a **sex pilus** to the other cell. Which is donor and which is recipient appears to be genetically determined.

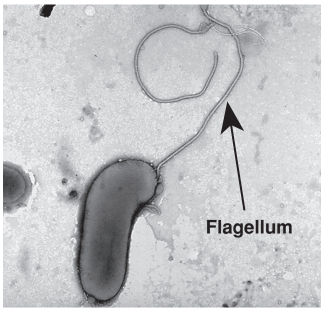


Periodicals:
Bacteria

Related activities*: Antibiotic Resistance, Features of Taxonomic Groups*
Web links*: Gram Stain Animation, Bacterial Conjugation Animation*

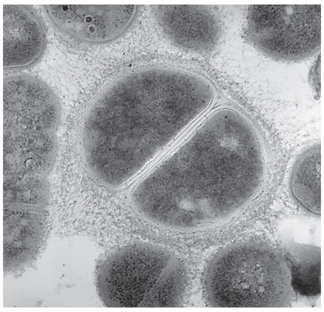


Campylobacter jejuni, a spiral bacterium responsible for foodborne intestinal disease. Note the single flagellum at each end (amphitrichous arrangement).



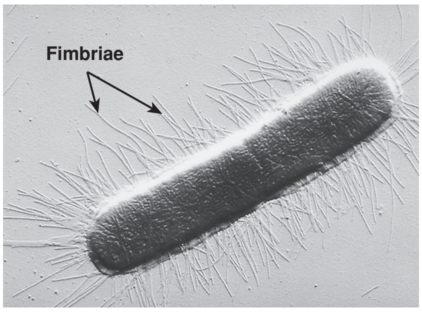
Helicobacter pylori, a comma-shaped vibrio bacterium that causes stomach ulcers in humans. This bacterium moves by means of multiple polar flagella.

A species of *Spirillum*, a spiral shaped bacterium with a tuft of polar flagella. Most of the species in this genus are harmless aquatic organisms.



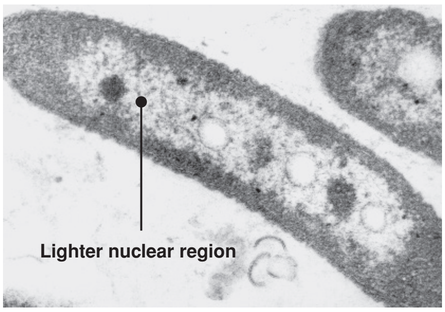
Bacteria usually divide by binary fission. During this process, DNA is copied and the cell splits into two cells, as in these gram positive cocci.

All photos this row: EII



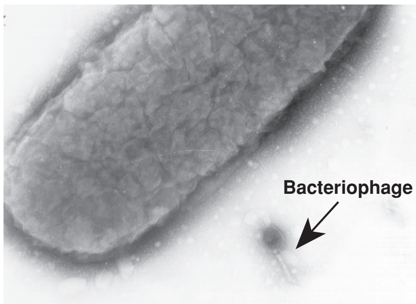
Escherichia coli, a common gut bacterium with **peritrichous** (around the entire cell) **fimbriae**. *E. coli* is a gram negative rod; it does not take up the gram stain but can be counter stained with safranin.

EII



TEM showing *Enterobacter* bacteria, which belong to the family of gut bacteria commonly known as enterics. They are widely distributed in water, sewage, and soil. The family includes motile and non-motile species.

WMU



SEM showing a large rod-shaped bacterium with an approaching bacteriophage (viral particle). The bacterium has hair-like **pili** (not visible) protruding from the surface which act as phage receptors.

WMU

1. (a) Describe the function of flagella in bacteria:

   (b) Explain how fimbriae differ structurally and functionally from flagella:

2. (a) Describe the location and general composition of the bacterial cell wall:

   (b) Describe how the glycocalyx differs from the cell wall:

3. (a) Describe the main method by which bacteria reproduce:

   (b) Explain how conjugation differs from this usual method:

   (c) Comment on the evolutionary significance of conjugation:

4. Briefly describe how the artificial manipulation of plasmids has been used for technological applications:

Levels of Organization

Organization and the emergence of novel properties in complex systems are two of the defining features of living organisms. Organisms are organized according to a hierarchy of structural levels (below), each level building on the one below it. At each level, novel properties emerge that were not present at the simpler level. Hierarchical organization allows specialized cells to group together into tissues and organs to perform a particular function. This improves efficiency of function in the organism.

In the spaces provided for each question below, assign each of the examples listed to one of the levels of organisation as indicated.

1. **Animals**: *adrenaline, blood, bone, brain, cardiac muscle, cartilage, collagen, DNA, heart, leukocyte, lysosome, mast cell, nervous system, neuron, phospholipid, reproductive system, ribosomes, Schwann cell, spleen, squamous epithelium.*

   (a) Molecular level: ______________________________

   ____

   (b) Organelles: ______________________________

   ____

   (c) Cells: ______________________________

   ____

   (d) Tissues: ______________________________

   ____

   (e) Organs: ______________________________

   ____

   (f) Organ system: ______________________________

   ____

   ____

2. **Plants**: *cellulose, chloroplasts, collenchyma, companion cells, DNA, epidermal cell, fibers, flowers, leaf, mesophyll, parenchyma, pectin, phloem, phospholipid, ribosomes, roots, sclerenchyma, tracheid.*

   (a) Molecular level: ______________________________

   ____

   (b) Organelles: ______________________________

   ____

   (c) Cells: ______________________________

   ____

   (d) Tissues: ______________________________

   ____

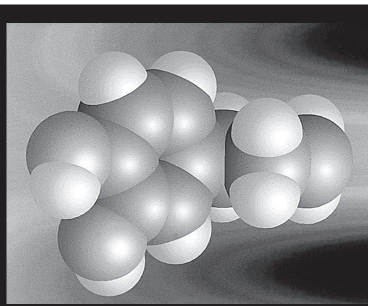
   (e) Organs: ______________________________

   ____

   ____

MOLECULAR LEVEL

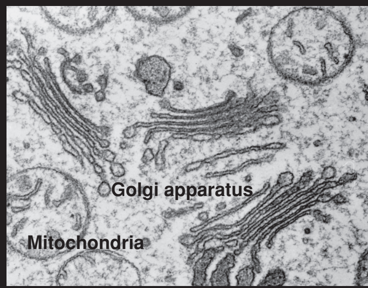
Atoms and molecules form the most basic level of organization. This level includes all the chemicals essential for maintaining life e.g. water, ions, fats, carbohydrates, amino acids, proteins, and nucleic acids.



ORGANELLE LEVEL

Many diverse molecules may associate together to form complex, highly specialized structures within cells called cellular organelles e.g. mitochondria, Golgi apparatus, endoplasmic reticulum, chloroplasts.

WMU



CELLULAR LEVEL

Cells are the basic structural and functional units of an organism. Each cell type has a different structure and function; the result of cellular differentiation during development.

Animal examples *include: epithelial cells, osteoblasts, muscle fibers.*

Plant examples *include: sclereids, xylem vessels, sieve tubes.*

EII

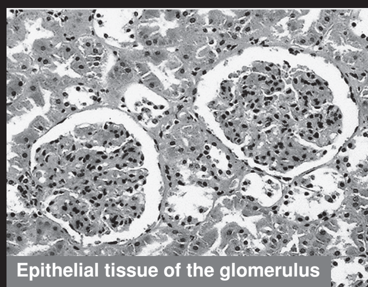
Epithelial cells

TISSUE LEVEL

Tissues are composed of groups of cells of similar structure that perform a particular, related function.

Animal examples *include: epithelial tissue, bone, muscle.*

Plant examples *include: phloem, chlorenchyma, endodermis, xylem.*



Epithelial tissue of the glomerulus

ORGAN LEVEL

Organs are structures of definite form and structure, made up of two or more tissues.

Animal examples *include: heart, lungs, brain, stomach, kidney.*

Plant examples *include: leaves, roots, storage organs, ovary.*

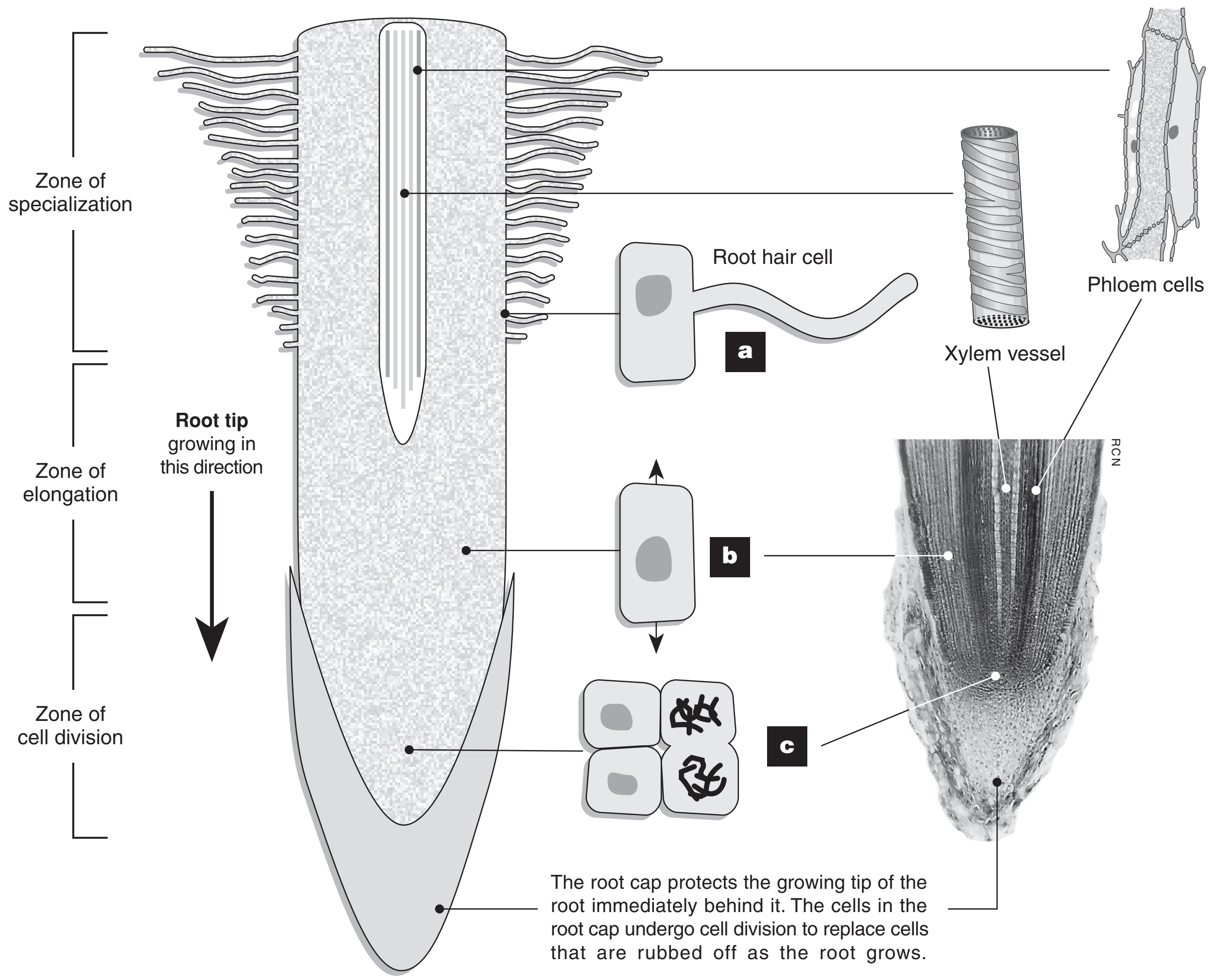
RCN

ORGAN SYSTEM LEVEL

In animals, organs form parts of even larger units known as **organ systems**. An organ system is an association of organs with a common function, e.g. digestive system, cardiovascular system, and the urinary system. In all, eleven organ systems make up the **organism**.

Root Cell Development

In plants, cell division for growth (mitosis) is restricted to growing tips called **meristematic** tissue. These are located at the tips of every stem and root. This is unlike mitosis in a growing animal where cell divisions can occur all over the body. The diagram below illustrates the position and appearance of developing and growing cells in a plant root. Similar zones of development occur in the growing stem tips, which may give rise to specialized structures such as leaves and flowers.



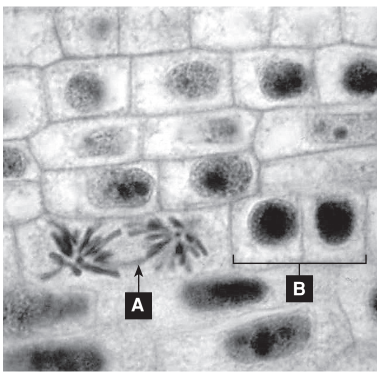
1. Briefly describe what is happening to the plant cells at each of the points labelled **a** to **c** in the diagram above:

   (a) ______________________________

   (b) ______________________________

   (c) ______________________________

2. The light micrograph (below) shows a section of the cells of an onion root tip, stained to show up the chromosomes.



   (a) State the mitotic stage of the cell labeled **A** and explain your answer:

   ____

   (b) State the mitotic stage just completed in the cells labeled **B** and explain:

   ____

   (c) If, in this example, 250 cells were examined and 25 were found to be in the process of mitosis, state the proportion of the cell cycle occupied by mitosis:

   ____

   ____

3. Identify the cells that divide and specialize when a tree increases its girth (diameter): ______________________________

***Related activities**: Mitosis and the Cell Cycle*

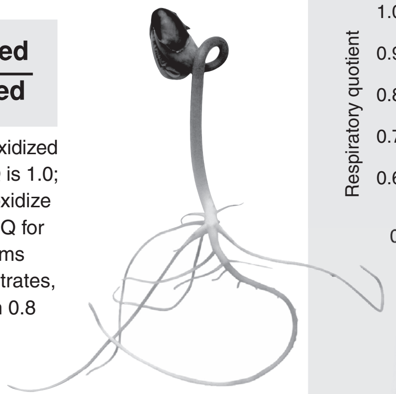
Measuring Respiration

In small animals or germinating seeds, the rate of cellular respiration can be measured using a simple respirometer: a sealed unit where the carbon dioxide produced by the respiring tissues is absorbed by soda lime and the volume of oxygen consumed is detected by fluid displacement in a manometer. Germinating seeds are also often used to calculate the **respiratory quotient** (RQ): the ratio of the amount of carbon dioxide produced during cellular respiration to the amount of oxygen consumed. RQ provides a useful indication of the respiratory substrate being used.

Respiratory Substrates and RQ

The respiratory quotient (RQ) can be expressed simply as:

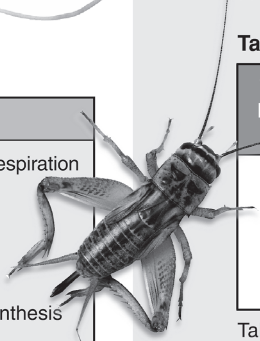
$$RQ = \frac{CO_2 \text{ produced}}{O_2 \text{ consumed}}$$



When pure carbohydrate is oxidized in cellular respiration, the RQ is 1.0; more oxygen is required to oxidize fatty acids (RQ = 0.7). The RQ for protein is about 0.9. Organisms usually respire a mix of substrates, giving RQ values of between 0.8 and 0.9 (see table 1, below).

Table 1: RQ values for the respiration of various substrates

RQ	Substrate
> 1.0	Carbohydrate with some anaerobic respiration
1.0	Carbohydrates e.g. glucose
0.9	Protein
0.7	Fat
0.5	Fat with associated carbohydrate synthesis
0.3	Carbohydrate with associated organic acid synthesis



Using RQ to determine respiratory substrate

Fig. 1: RQ in relation to germination stage in wheat

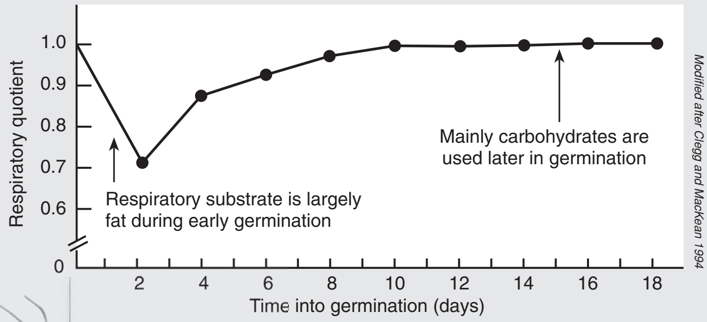


Fig. 1, above, shows how experimental RQ values have been used to determine the respiratory substrate utilized by germinating wheat seeds (*Triticum sativum*) over the period of their germination.

Table 2: Rates of O_2 consumption and CO_2 production in crickets

Time after last fed (h)	Temperature (°C)	Rate of O_2 consumption ($mlg^{-1}h^{-1}$)	Rate of CO_2 production ($mlg^{-1}h^{-1}$)
1	20	2.82	2.82
48	20	2.82	1.97
1	30	5.12	5.12
48	30	5.12	3.57

Table 2 shows the rates of oxygen consumption and carbon dioxide production of crickets kept under different experimental conditions.

1. Table 2 above shows the results of an experiment to measure the rates of oxygen consumption and carbon dioxide production of crickets 1 hour and 48 hours after feeding at different temperatures:

   (a) Calculate the RQ of a cricket kept at 20°C, 48 hours after feeding (show working): ______________________

   (b) Compare this RQ to the RQ value obtained for the cricket 1 hour after being fed (20°C). Explain the difference:

   ____

   ____

2. The RQs of two species of seeds were calculated at two day intervals after germination. Results are tabulated to the right:

   (a) Plot the change in RQ of the two species during early germination:

   (b) Explain the values in terms of the possible substrates being respired:

   ____

   ____

   ____

   ____

   ____

   ____

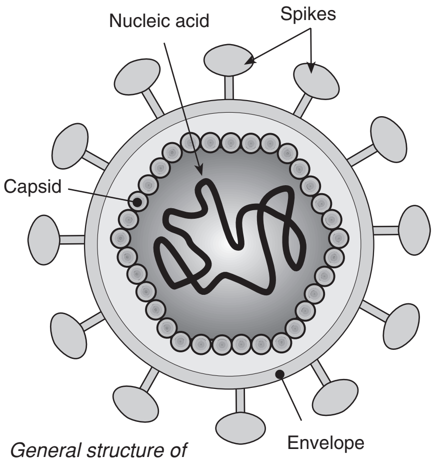
   ____

Days after germination	RQ	
	Seedling A	Seedling B
2	0.65	0.70
4	0.35	0.91
6	0.48	0.98
8	0.68	1.00
10	0.70	1.00

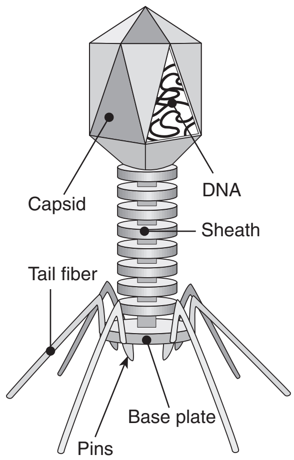
The Structure of Viruses

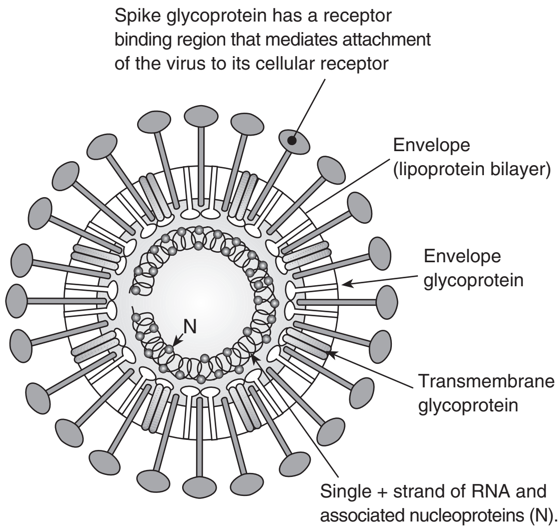
Viruses are non-cellular **obligate intracellular parasites**, requiring a living host cell in order to reproduce. The traditional view of viruses is as a minimal particle, containing just enough genetic information to infect a host and hijack the host's machinery into replicating more viral particles. The identification in 2004 of a new family of viruses, called **mimiviruses**, forced a rethink of this conservative view. Mimiviruses overlap with parasitic cellular organisms in terms of both size (400 nm) and genome complexity (over 1000 genes) and their existence suggests a fourth domain of life. A typical, fully developed viral particle (**virion)** lacks the metabolic machinery of cells, containing just a single type of nucleic acid (DNA or RNA) encased in a protein coat or **capsid**. Being non-cellular, they do not conform to the existing criteria upon which a five or six kingdom classification system is based. Viruses can be distinguished by their structure (see below) and by the nature of their genetic material (single or double stranded DNA or RNA). Many are difficult to study because they require living animals, embryos, or cell cultures in order to replicate.

Diversity in Viral Structure

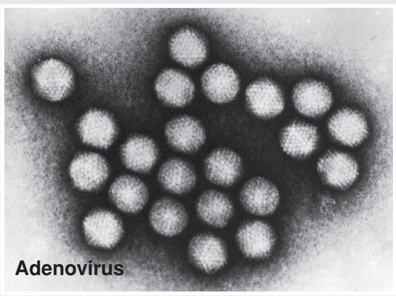


General structure of an enveloped animal virus, e.g. Herpesvirus



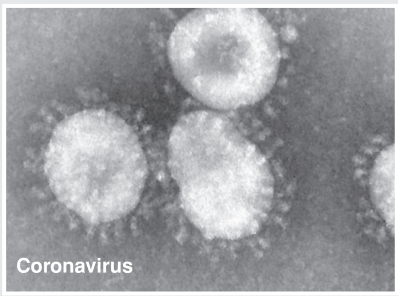


General animal virus **Bacteriophage** **Coronavirus**



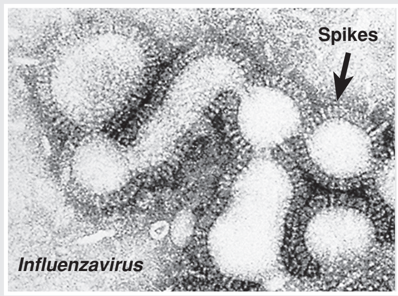
CDC

Adenoviruses are medium-sized (90-100 nm), nonenveloped viruses containing double-stranded DNA. They most commonly cause respiratory illness and are unusually stable to chemical or physical agents, allowing for prolonged survival outside of the body.



CDC

Coronaviruses primarily infect the upper respiratory and gastrointestinal tracts of birds and mammals, including humans. Their name derives from the crown or corona of spikes and they have the largest genome of any of the single stranded RNA viruses.



In some viruses, the capsid is covered by an **envelope**, which protects the virus from the host's nuclease enzymes. Spikes on the envelope provide a binding site for attachment to the host. ***Influenzavirus*** is an enveloped virus with many glycoprotein spikes.

1. Describe the basic structure of a generalized viral particle (virion): ____________________

2. Explain why viruses are such a difficult group to classify conventionally: ____________________

3. Outline why viruses are classified as obligate intracellular parasites: ____________________

4. Explain why many viruses are difficult to culture: ____________________

Related activities: *Replication in Animal Viruses, Replication in Bacteriophages*

Periodicals: *Are viruses alive?*